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ORIGINAL ARTICLES.

Artichthyocrinus, n.g., a Flexible Crinoid from the Carboniferous Limestone of Fife.

By JAMES WRIGHT.

IN the Transactions of the Edinburgh Geological Society (vol. x, 1912, p. 49, pl. v, f. 8) I gave a figure of an Ichthyocrinid which occurred in No. 1 Bed, Invertiel, along with other members of the family, all of which were referred to *? Forbesiocrinus*. In the spring of 1913 I had the pleasure of sending my specimens of flexible crinoids to the eminent crinoid authority, Dr. Frank Springer, of the United States Museum, Washington, who was then engaged on a comprehensive study of the group. For some reason or other I did not forward this particular specimen, probably because I did not think it well enough preserved (No. 939, Fig. 3 of present paper). The other Ichthyocrinids from Invertiel were referred by Springer to his new species *Amphicrinus scoticus*. It so happens that No. 939 was the only specimen of its kind which I had at that time cleaned and mounted in my collection, although as the sequel will show it is evident that I had found several others in the field, but had erroneously laid them aside as *Amphicrinus scoticus*. This is a mistake which could easily be made, since I was not then fully aware of the special characters which distinguished *A. scoticus*.

After receiving a copy of that magnificent work, *The Crinoidea Flexibilia* (reviewed by Dr. Bather in the GEOLOGICAL MAGAZINE, 1922, Vol. LIX, p. 177), I was led to examine three specimens, two from Invertiel and one from Roscobie (Figs. 1, 4, 11), which I had shortly before cleaned and mounted, and I found they were identical with No. 939, and belonged to a form which did not appear to be figured or described in Dr. Springer's new work. On communicating these facts to Dr. Springer and sending him a diagram based on these four specimens he sent me a letter from which he has been good enough to allow me to quote as follows: "You were quite right in thinking that it does not agree with any of the Flexibilia illustrated in my monograph. It represents in fact a new generic type, taking a well-defined place in the family Ichthyocrinidæ. The form is conspicuous at a glance for being without radianal or anal plates, and having the posterior basal undifferentiated.

From the two genera which possess this structure, viz. *Metichthyocrinus* and *Wachsmuthicrinus*, it is thoroughly differentiated; from the former, which it superficially most nearly resembles, by its well-developed interbrachial plates, and from the latter by its dichotomous arms. That the presence of interbrachial plates is not a mere sporadic variation (as happens occasionally in single inter-rays of *Metichthyocrinus*) is proved by their uniform occurrence throughout all the areas in four specimens from two different localities. Besides, it comes from a different and very much later horizon than these two genera.

"In view of these facts, there is no escape from recognizing in this interesting form a new generic type, which will simply add one more to the almost unlimited modifications of which the crinoid skeleton is capable.

"Such a modification as this is quite logical, considering the relative stratigraphic position of the respective genera. As I have stated in the Flexibilia monograph, p. 340, the Hurlet Limestone may be approximately correlated with the Kaskaskia (Chester) member at the close of the American Lower Carboniferous—a horizon which is by a very long step later than the Burlington Limestone and its equivalents, in which *Metichthyocrinus* and *Wachsmuthicrinus* occur. Thus the Scottish form, geologically, is widely separated from its American relatives, and, furthermore, the modifications by which it is specially distinguished, viz. the increase of interbrachials and the elimination of anal structures, are both characters which tend to develop in the phylogenetic history of the group (*Crin. Flex.*, pp. 55, 57, etc.). Therefore, their concurrent appearance combined in a single form thus later in the geological scale is quite consistent with what might be expected. I would therefore suggest that you propose a new genus for the reception of this very distinct form."

After receiving this letter I made a further search throughout my unmounted collection—an accumulation of over twenty-two years of duplicates and other specimens laid aside for cleaning and future study—and I have been able to identify another fourteen individuals belonging to the new form, all of which confirm in a remarkable way the dominant character of the genus, namely, the presence of an interbrachial plate in each of the inter-radii. This additional material, however, shows certain modifications from the four specimens already mentioned, such as the appearance in two specimens of an additional interbrachial linking-up with the posterior basal, and the occasional absence, superficially, of an interbrachial, etc. Communicating details and drawings of these to Dr. Springer, he further says: "The new facts you have found in your Ichthyocrinid genus, viz. the occasional absence of an iBr, and the presence in two specimens of an additional iBr in one inter-radius connecting with the basal, etc., are not surprising to me, and the occurrence must be treated as a variation

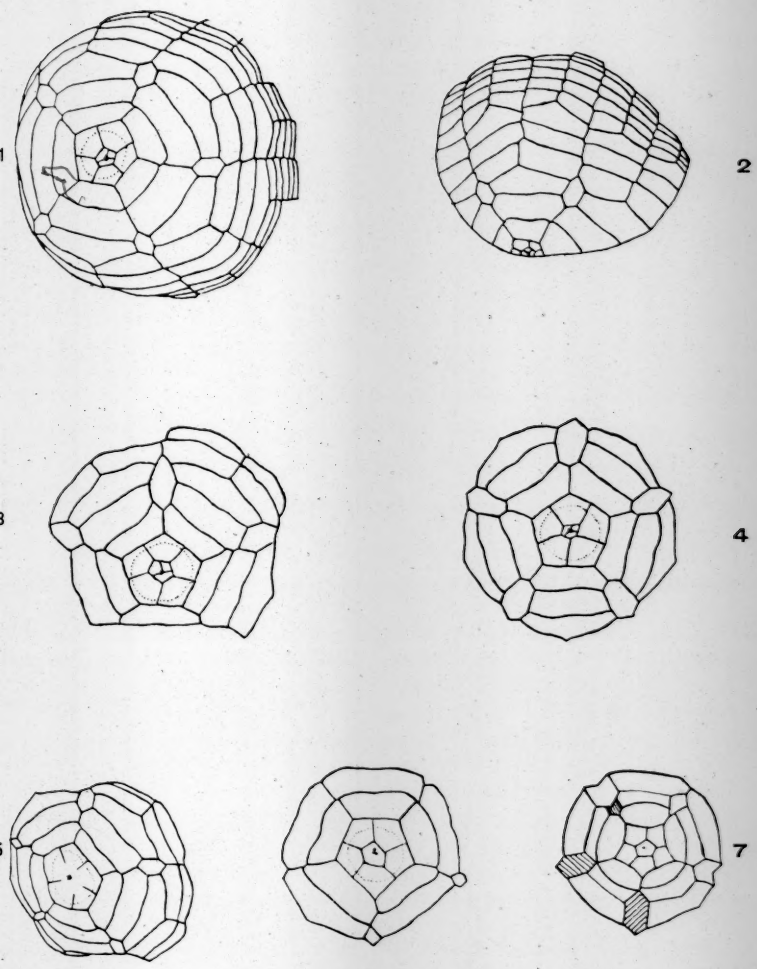


Fig. 1. Specimen No. 665, from posterior. Fig. 2. Specimen No. 665, side view showing right posterior and right antero-lateral rays, anal iBr to left. Fig. 3. Specimen No. 939. Fig. 4. Specimen No. 940. Fig. 5. Specimen No. 2182. Fig. 6. Specimen No. 2179. The notches on left, and top right, of figure were filled by the iBr, which showed on the surface like the two seen in lower part of figure. Fig. 7. Diagrammatic view of interior of 2179 for comparison with Fig. 6. The shaded plates are the iBr present in the specimen and shown in Fig. 6; the unfilled notches extending outward to the surface correspond with those on left and top right. The remaining notch is only seen when the cup is viewed from the interior; the iBr which filled it is not shown on the surface. Figs. 1 and 2 from Roscobie, the others from No. 1 Bed, Invertiel. All author's collection. All figures $\frac{3}{2}$ natural size, except Fig. 2, which is slightly under that scale.

incident to the late occurrence in the geological scale, when the Flexibilia group was on the eve of extinction. Such an instability of characters is not infrequent in a group, and a variation of this kind does not affect the validity of the genus (*Crin. Flex.*, pp. 419, 191, etc.)."

I have accordingly pleasure in acceding to Dr. Springer's suggestion, and propose the following for the reception of the new material.

Family—ICHTHYOCRINIDAE Angelin.

ARTICHTHYOCRINUS [1] new genus.

An Ichthyocrinid with rays above radials partly separated by solid plates arched over by brachials. Crown expanding from radials up. Infrabasals entirely within ring of basals. No radianal. Posterior basal and anal not usually differentiated. Interbrachials few, usually limited to a single plate. Primibrachs two. Arms dichotomous. Column large covering infrabasals.

Genotype, *Artichthyocrinus springeri*, new species.

Specimens rather smaller than the average of *Amphicrinus scoticus*, with which it is closely associated at the type localities (average of *A. scoticus* as given by Dr. Springer, *Crin. Flex.*, p. 338, greatest width at $IIIBr_3$, 35 mm., greatest height, 40 mm.). Crown sub-globose to ovoid, tending to be wider than high. Surface smooth. Greatest width of best-preserved specimens, No. 665, Figs. 1 and 2, at $IIIBr_4$, 24·7 mm. Greatest height 17 mm. Across base, from outer edges of RR, 8 mm. No. 2171, Figs. 8 and 9. Greatest width at $IIIBr_4$, calculated 27 mm. Greatest height, 13·7 mm. Across base from outer edges of RR, 11 mm. Average width of base in the Invertiel specimens, from outer edges of RR, 9 mm. Base very shallow. IBB small, entirely within BB. Post. B not usually differentiated. Outer margins of BB well shown beyond the column facet, exceptionally covered by column. iBr usually as a single plate in each IR; occasionally two iBr in Anal IR; IBr, two; IIBr, three; IIIBr, five or more. Arms flat. Sutures arcuate, more strongly marked in distal parts of rays. Average diameter of column facet, 4·9 mm. Specimens rare compared with *Amphicrinus scoticus*.

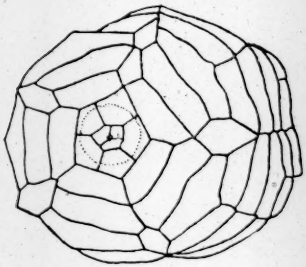
Holotype.—No. 2171, Jas. Wright Collection.

Distribution.—Seafield Tower Limestone (No. III Limestone of Kirkcaldy-Kinghorn Coast Section, "Hurlet" of Survey Memoir), Lower Carboniferous, Scotland.

The material under discussion consists of eighteen specimens numbered 659, 665, 938, 939, 940, 941, 942, 944, 2171, 2178, 2179, 2180, 2181, 2182, 2183, 2184, 2185, 2186. J. Wright Collection. All are from No. 1 Bed, Invertiel, near Kirkcaldy, except No. 665 (Figs. 1 and 2), which is from Roscobie, near Dunfermline, and No.

[1] ἄρτιος, complete, exactly fitted.

659, which is from Seafield. The formation at all these localities is the No. III Limestone (Seafield Tower Limestone) of the Kirkcaldy-Kinghorn coast section, usually termed the "Hurlet" (Geol. Survey Memoir on Central and Western Fife and Kinross, 1900).



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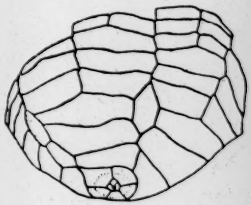

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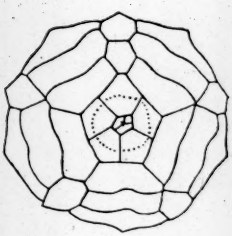

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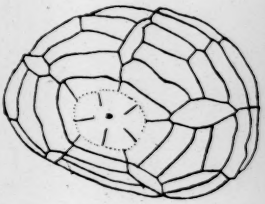

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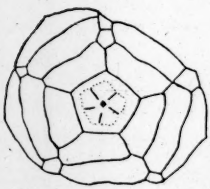

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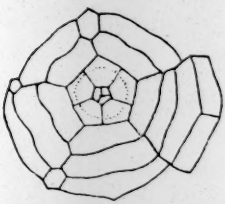

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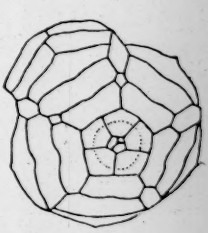

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Fig. 8. Specimen No. 2171, from posterior. Fig. 9. Specimen No. 2171, side view showing right posterior and right antero-lateral rays, anal iBr to left. Fig. 10. Specimen No. 2178. Fig. 11. Specimen No. 942. Fig. 12. Specimen No. 938. Fig. 13. Specimen No. 2180. Below the two interradii on the right there are notches for the reception of iBr which did not appear on the surface. Fig. 14. Specimen No. 2181. When this specimen is viewed from interior the missing iBr at left bottom of figure—in left anterior IR—is seen in place under suture lines of primibrachs. All author's collection, No. 1 Bed, Invertiel. All × $\frac{3}{2}$, except Fig. 9, which is slightly under that scale.

Prof. Macnair, of Glasgow, considers it to be the equivalent of the Main Hosie of the West of Scotland. However that question may be ultimately settled, one thing may be definitely stated, namely, that from a crinoidal standpoint it is the most important horizon in the Lower Carboniferous Limestone Series in the West of Fife, none of the underlying or overlying limestones equalling it for abundance and preservation of crinoid remains (Wright, *Trans. Edin. Geol. Soc.*, vol. x, 1912, pp. 49, 148).

Of the 18 specimens, 11 are figured herewith (Nos. 665, 939, 940, 2182, 2179, 2171, 2178, 942, 938, 2180, 2181, Figs. 1 to 14), and give a fair idea of the characters of the species and the variations by which it is distinguished. All the figures are outline drawings from photographs. The chief difficulty in drawing the specimens has been in making out the infrabasal plates. In Nos. 2182, 2179, Figs. 5 and 6, for example, the suture lines between these plates cannot be determined with certainty and it cannot therefore be stated which is here the anal inter-radius. The same applies to 942, 938, Figs. 11 and 12, where the central area in both specimens is somewhat imperfect and crushed. Even the suture lines of the basals can only with difficulty be made out. Specially to be noted in these two specimens is the fact that the proximals encroached well over on to the radials and entirely hid the basals. It is quite possible that the IBB were resorbed, as happens not infrequently in *Amphicrinus scoticus*. All the other specimens gave little difficulty, and in most the basals are easily seen within and outside the column facet. When the column was in position, a fair proportion of these plates was visible (dotted circles in figures represent column facet).

All the specimens are well preserved, but none are quite complete as to arm structure, although No. 665 (Figs. 1 and 2) is nearly so and shows the rays well up to $III Br_5$, beyond which they are closely infolded. No. 2171 (Figs. 8 and 9) has the arms well preserved on one side only, up to $III Br_4$ in the right antero-lateral ray. These specimens specially show that the arm structure is dichotomous.

As to size, the new species is rather smaller than the average of *Amphicrinus scoticus*, its nearest relative at the type localities.

As to shape, this appears to depend a good deal on the size and position of the interbrachials. When they attain their full size, as in Nos. 840, 2171, 2178 (Figs. 4, 8, and 10), the calyx tends to be globular instead of inclining to be somewhat more elongated or ovoid, as in Nos. 938, 2180, 2181 (Figs. 12, 13, 14, etc.). In general, however, the aspect of *Artichthyocrinus springeri* is not unlike *Amphicrinus scoticus*, and in the shaly condition in which both species are found in the field one might easily be mistaken for the other.

It has been stated that the presence of interbrachials is a dominant character of the genus, although as shown by Nos. 2180, 2181 (Figs. 13 and 14) some of these plates are absent. This, however,

is a superficial character only, as I have been able to clean these specimens to show the interior of the calyx, and when the plates themselves are not present notches for their reception are clearly visible. It can therefore be stated definitely that an interbrachial (occasionally two) occurred without exception in all the inter-radii in every one of the eighteen specimens.

In No. 2179, Fig. 6, the unfilled notches on left and top right of figure were occupied by interbrachials, as is clearly shown when the specimen is viewed from the interior, and these plates were exposed on the outside of the calyx in the lifetime of the crinoid. In Fig. 7, which is a diagrammatic view of the interior of the same specimen, it will be observed that below the right top notch—corresponding to the left top of Fig. 6—a small shaded plate lies below. There is no indication whatever of this plate on the outside of the calyx, so that in this inter-radius there were two plates, the larger of which only showed on the surface. From the evidence of the other specimens, it is probable this is the anal IR. Another interesting feature about this specimen is that the top left IR of Fig. 6 did not show any interbrachial on the surface of the calyx, but in the corresponding position in the interior, top right of Fig. 7, a rather long narrow wedge-shaped notch is seen. This was certainly filled by an interbrachial which did not penetrate to the outside.

Features like this occur in another two specimens, Nos. 2180, 2181 (Figs. 13 and 14). In Fig. 13 the two inter-radii on the right show no iBr, but in the interior of the specimen there are notches or recesses for the reception of single iBr. Above the notches the ends of the primibrachs which covered them are very thin. In 2181 (Fig. 14), when viewed from interior, the missing iBr on left bottom of figure is well seen in place under the suture lines of the primibrachs. It is a small hexagonal plate, its lower edge touching the RR and its upper the iBr_2.

With these exceptions, the interbrachials are well developed outwardly in all the other specimens. In most cases they are hexagonal, but vary a good deal in their exact position in the IRR. As a whole, their angles where they meet the adjoining plates are well defined, but occasionally, as in No. 942 (Fig. 11), their lines are somewhat irregular. Probably the large plate on the right of this figure is in the anal IR. The position of these plates in the inter-radii has been in all cases accurately ascertained, and may be noted from the figures, from which it will be observed that no two specimens are exactly alike in this respect. One may note such a perfect pattern as No. 940 (Fig. 4), in which the lower ends of the iBr connect up with the RR in all the inter-radii, ranging through various modifications to irregular examples as Nos. 938, 2180, 2181 (Figs. 12, 13, and 14). Then there are the two specimens mentioned in Dr. Springer's letter, Nos. 2171, 2178 (Figs. 8, 9, and 10), which show two plates in the anal IR, the lower of which

connects up with the post. basal. The post. B in both specimens is not noticeably larger than the other BB ; but in No. 2178 (Fig. 10) it is more truncated than in No. 2171 (Fig. 8). We have here no doubt a reminiscence of an ancestral character which we see fully developed in such forms as *Eurycrinus* and *Amphicrinus*. Another variation is that shown in No. 938, Fig. 12, in which there are two plates in one inter-radius—top of figure—the lower of which meets the radials but is not connected with the basal. Probably these plates lie in the anal IR, if we may judge correctly from Figs. 9 and 10. Then again we have another variation, as shown in No. 2181 (Fig. 14), with two plates in the anal IR, the lower of which meets the radials and, as in No. 938, is separated from post. B. Further, we have in the left posterior IR two plates which are separated from one another, the only instance of this kind among the specimens.

As may be noted, the size of the interbrachials varies considerably. The smallest is that shown in No. 938, Fig. 12, in what is probably the left post. IR (left of figure). Its greatest length is about 1·9 mm., and greatest width 1·5 mm. The largest is that shown in No. 942, Fig. 11 (right of figure), with a greatest length of 7 mm. and greatest width of 2·8 mm. Between these extremes there are many gradations. In the specimens in which the single interbrachials are most prominent, the largest of these plates is usually in the anal IR, but in specimens like No. 940 (Fig. 4) or No. 665 (Fig. 1) little or no difference can be detected.

The following additional details may be of interest. Of the eighteen specimens :—

11 have a single well-developed iBr in each IR, as in Figs. 1, 3, 4, 11.

1 has a single iBr in each IR, but in two of the IRR the iBr are not shown on surface (Fig. 13).

2 have a single iBr in each IR, except anal, in which there are two plates connected with post. B (Figs. 8, 10).

2 have a single iBr in each IR, except ? anal, in which there are two plates, the lower of which meets the radials only and is separated from post. B (Figs. 6, 7, 12). In Figs. 6 and 7 the lower ? anal plate and iBr in left post. IR, not shown on surface.

1 has a single iBr in three IRR, one of which did not appear on the surface, two iBr in anal not connected with post. B, two iBr in left post. IR separated from one another (Fig. 14).

1 an abnormal specimen, with only four IRR, a single iBr in each IR, No. 944, not figured.

Total 18.

It has not been possible to clean out the interior of every specimen, but it is probable that, even in the normal type, which outwardly only show a single well-developed iBr, there may occasionally occur

in the interior more than one iBr (*Crin. Flex.*, p. 55). This is indicated by Fig. 7, and also by another specimen, No. 2186—not figured—which shows in the interior two plates in two IRR, the lower only in these cases being seen on the outside. Outwardly, this specimen is similar to Figs. 1, 3, 4, 11.

The column is shown in specimen No. 659, which is a crushed crown with about four inches of the column in place. Unfortunately, a few of the proximal columnals are missing, but it does not appear that these were of greater diameter than the others. The column facet in this specimen measures 4·7 mm., and the diameter of the columnals measures about the same throughout the entire length preserved. So far as can be seen, the column is smooth, and composed of alternating thin and thicker ossicles with, at varying distances, a specially thick one which bears cirri.

Thickness of thin columnals . . . ·4 mm.
,, thick columnals . . . ·8 mm.
,, cirriferous columnals . . 1·5 mm.

Variations such as those indicated and as shown by the figures are no doubt what one might expect in such a highly specialized form (*Crinoidea Flexibilia*, p. 419, etc.). They are certainly extremely interesting and instructive, occurring as they do in a single species and in a comparatively small number of specimens. They recall in some ways an examination made several years ago on the Inadunate forms *Eupachycrinus* and *Zeacrinus* from the same localities, in which, among over 200 cups, considerable instability of characters was noted not only in the shape of the cups, but also in the position and arrangement of the radianal and anal plates (*Trans. Geol. Soc. Glasgow*, vol. xvi, 1920, p. 364).

At Invertiel and Roscobie, *Artichthyocrinus springeri* occurs with other species of Flexibilia as follows :—

Invertiel.

Amphicrinus scoticus Springer.
Synerocrinus incurvus Trautchold.
Onychocrinus Wrighti Springer.
,, sp.
Mespilocrinus Koninckı Hall
,, near *Forbesianus* de Kon. & Le Hon.
,, sp.

Roscobie.

Amphicrinus scoticus Springer.
Synerocrinus incurvus Trautchold.
Onychocrinus sp.

Associated with the Flexibilia at both localities are many species, some undescribed, of Inadunate, Adunate, and Camerate forms, like *Eupachycrinus*, *Zeacrinus*, *Woodocrinus*, *Ulocrinus*, *Poteriocrinus*, *Hydreionocrinus*, *Scytalecrinus*, *Platycrinus*, *Dichocrinus*, and *Rhodocrinus*. It is rather a curious circumstance that in

these Fife localities we have an exceedingly rich crinoid fauna fully representative of the groups into which the Crinoidea have been divided. Although the list of Flexibilia given here is not large it is characteristic, and, at Invertiel especially, *Amphicrinus scoticus* and *Mespilocrinus* near *Forbesianus* are abundant and well preserved. This relative abundance of Flexibilia is noteworthy since, as stated by Dr. Springer (*Crin. Flex.*, p. 24), at some localities in America with an abundant and well-preserved crinoid fauna, not a single specimen belonging to the Flexibilia has ever been found.

In conclusion, I have to thank Dr. Springer for allowing me to quote from his letters and for other kindnesses. I have also to thank Dr. Bather for kind assistance in preparing this paper for publication and for valuable suggestions and advice.

The Distribution of Heavy Minerals in the Rocks of Western Togoland.

By Thomas Robertson, B.Sc., A.Inst.M.M.

General Description of the Country.

During the course of a reconnaissance mineral survey of Western Togoland in 1918–19 many streams were panned, and the concentrates were afterwards examined to ascertain to what extent the heavy minerals in them could be used as a guide in geological mapping.

The area under discussion is shown in Fig. 1. The dominating geographical feature is the Togo Mountain Range which traverses the country in a direction approximately north and south, but changes to N.N.E.–S.S.W. to the south of Misahöhe and continues on the west of the Volta River towards Accra as the Akwapim Range. North of Misahöhe it gradually broadens out into a plateau. Southwards it splits into two lines of peaks, the eastern of which practically dies out south of Ho, whilst the western branch continues over the Gold Coast border towards Anum as the Peki Range. The highest point is about 3,000 feet above sea-level. This is in the neighbourhood of Misahöhe. A parallel chain of hills runs north and south about twelve miles west of the Togo Range, but does not attain at any point a height of over 2,800 feet (usually much less) and is discontinuous. The different portions of this chain are referred to below by the following names: Kpandu Hills, Nkunya Hills, Tapa Hills, and Tutukpene Hills. The ground between the Togo Range and the Kpandu and Nkunya Hills is drained by the Davi River, and that between the Togo Range and the Tapa and Tutukpene Hills by the Asuokoko and its tributary the Menu. North-west of the high country is the broad undulating valley of the Oti River, which is an eastwards extension of the Gold Coast Northern Territories. To the south-east of the Togo Range a low stretch of plain drained by the Kalagba, Todshi, Shio, and Haho Rivers extends

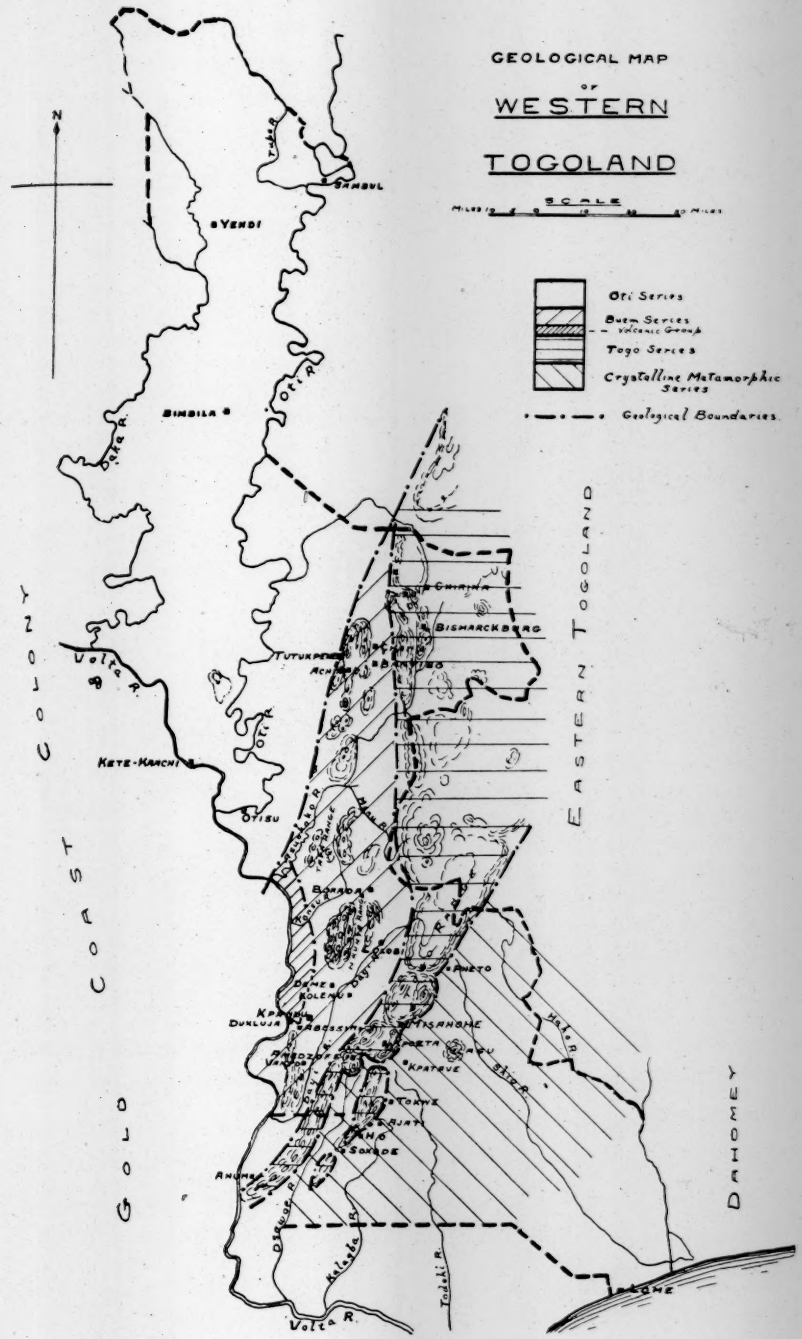

FIG. 1.—Geological Map of Western Togoland.

to the coast. This latter plain is dotted over with isolated hills and small lines of peaks, the most important being Agu Mountain, a small residual group of peaks a few miles south-east of Misahöhe which reaches an altitude of over 3,000 feet above sea-level.

We have thus three distinct geographical divisions: (1) the valley of the Oti in the north-west, (2) the hill country running diagonally across the middle, and (3) a peneplain in the south with relict mountains.

Geologically, the country is divisible into different sections which correspond in great measure with the geographical divisions.

(1) The Oti series, a group of nearly horizontal sandstones, conglomerates, mudstones, etc., occupies the low-lying Oti valley and stretches from beyond the northern boundary of the country southwards to the mouth of the Asuokoko River. Westwards it extends into Gold Coast territory, and eastwards reaches the foot of the Tutukpene Hills.

(2) The Buem series of altered sandstones, conglomerates, and mudstones, with associated volcanic rocks, covers the ground between the Oti Valley and the western scarp of the Togo Range, i.e. the hill chains west of the Togo Range and the valleys of the Asuokoko, Konsu, and Dayi Rivers.

(3) The Togo series, chiefly altered sedimentaries, e.g. quartzite and phyllite, forms the hills of the Togo Range. The Ho branch of the range is an outlier of Togo rocks resting on crystalline metamorphic rocks.

(4) The Crystalline Metamorphic series of gneisses and schists, with associated intrusive igneous rocks of various types, underlies the remainder of the country from the Togo Mountains southeastwards towards the sea.

No conclusive evidence of the age of these series has as yet been obtained. The Oti rocks rest unconformably on those of the Buem series, which in their turn appear to be younger than the more highly metamorphosed rocks of the Togo series. These last lie unconformably on the Crystalline Metamorphic rocks.

Method of Examination of Concentrates.

The results obtained on examination of a concentrate got by panning a stream in the ordinary way cannot be considered as of more than the very slightest quantitative value in indicating the type of rock traversed by the stream. This is due (1) to the smallness of the sample taken unless the prospects are encouraging, namely 6 to 12 small pans usually (50 to 100 lb. or so); (2) to the fact that the material is chiefly taken at places where the heavier minerals are most likely to be concentrated; and (3) to the extreme irregularity in distribution of the material in the average stream bed.

Qualitatively the value of the concentrate is greater, and in most cases the nature of the minerals found gives a good indication of the type of rock over which the stream flows.

The total amount of the concentrate being generally small, and its quantitative composition being unimportant, the method of examination adopted was very simple. The concentrate was spread out on paper and a dip sample taken with a spatula. The sample was placed on a glass slip and covered with an oil having a refractive index equal to about the mean refractive index of quartz. This made the majority of the grains with low refractive index (mainly quartz) very inconspicuous, whilst showing up clearly the more important minerals. The results were checked by taking and examining another sample in the same way.

Description and Distribution of Mineral Species.

Zircon.—This is present in practically every concentrate and is usually by far the most abundant constituent. It usually occurs in somewhat rounded crystals, but rounded grains, angular fragments, and unworn crystals with well-developed faces are also very common. The crystals vary in length from ·01 cm. to ·03 cm., anything outside these limits being quite uncommon. The length of the crystal is usually about 3 to 3½ times its breadth. In certain districts, however, the more needle-like type is common and at other places decidedly stumpy forms are frequent.

Usually the crystals are clear and colourless, with few inclusions. Zoning is not common, but most concentrates show a few zoned crystals. The zoning is of two types. (1) That in which growth has taken place equally on all faces (Fig. 2 (a)). This is the more common. (2) That in which growth has only taken place lengthwise (Fig. 2 (b)). This would naturally tend to produce needle-like crystals.

A geniculate twin was found in the concentrate from the Bla River between Kpatave and Misahöhe (Fig. 2 (d)). This was the only twinned zircon seen during the examination.

The zoning of the crystals is usually regular, the shadow crystals corresponding in development to the final crystal outline. In some cases, however, misshapen shadows appear inside well-developed crystals (Fig. 2 (c)). This is not very common, however. In some cases the zircon crystal contains a darker central zone, usually dark brown, from which cracks may radiate through the surrounding clear mineral. It seems in this case as if the outer zone were of different composition to the core, which may possibly be xenotime.

In many cases the crystals are cloudy or milky in appearance, probably due to decomposition. In other cases they are nearly opaque with tiny inclusions. As a general rule the inclusions do not lie in very definite zones though they may be concentrated near the centre. They are seldom in strictly regular or parallel growth either with one another or with the zircon crystal.

Though the mineral is usually colourless, coloured varieties are quite common, even apart from the brownish iron-staining which is

common in concentrates from the Buem volcanic zone and from the Oti series.

Pale yellow to yellowish green zircons are rare in the older rocks, but are very common in the Oti region. One or two from the Tonyo River on the Dayi Plateau were slightly pleochroic.

Greyish, rather smoky crystals appear in some of the concentrates, but do not seem to be characteristic of any definite region.

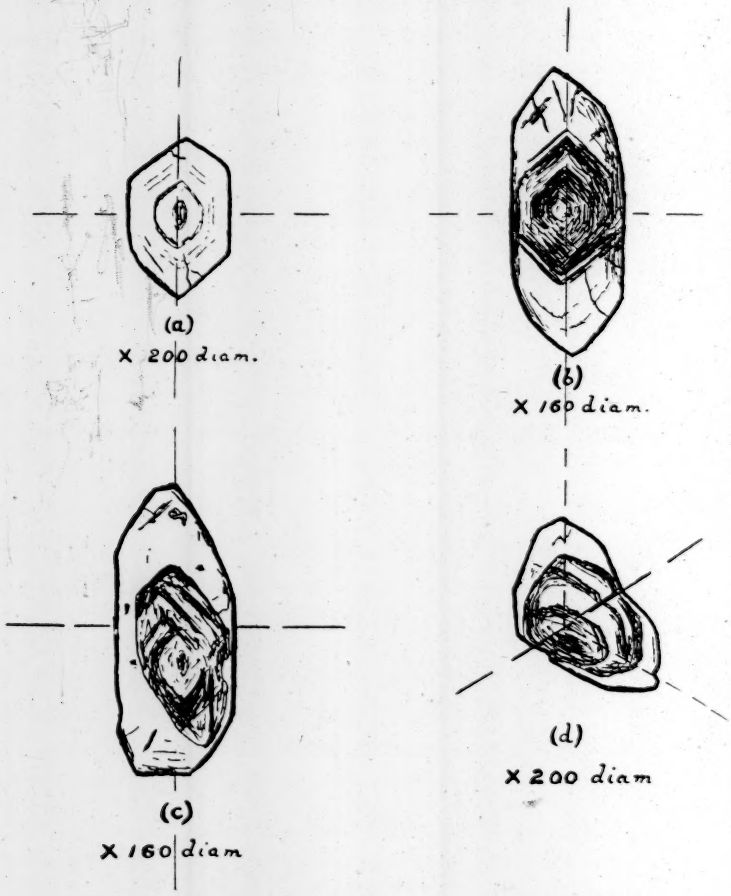

FIG. 2.—Zircon Crystals from Western Togoland.

Pink to purplish tints are very common in concentrates from streams flowing over rocks of the Togo series. They are so uncommon in the streams of the other regions that it was possible in many instances to use their occurrence in a stream as definite evidence of the presence of rocks of the Togo series in its higher

reaches. They appear to come chiefly from the schists and phyllites, and are not abundant in the quartzite members of the series. The most common colour is pale pink. Less frequently they have quite a purplish tinge and are distinctly pleochroic, α pink to purple, γ yellowish green. They are commonly more rounded than the colourless zircons in the same concentrate and so possibly not so hard. It was at first thought that they might be xenotime. To test this they were covered with a solution of sulphur in methylene iodide with refractive index nearly 1·77. In no case was the lower index of the mineral found to be below that of the liquid, so that the mineral must in every case be presumed to be zircon.

In a stream near Krachi, in the Oti region, some of the zircons showed the basal cleavage in broken fragments. This is quite unusual.

Iron Ores.—No detailed examination of these was undertaken, but tests on representative concentrates with a weak magnet made it apparent that much of the black sand was not magnetite, but probably ilmenite. Most of the shapeless grains were regarded as ilmenite and a partial confirmation of this was obtained in some cases by the reddish colour of some faces in reflected light.

Although nearly every stream panned yielded some iron ore in the concentrate, the quantity found varied considerably. On the east side of the Togo Range, the streams between Ajati and Tokwe yielded abundant black sand, but elsewhere the amount was not very great. Streams flowing off the Togo Range in most cases yielded scanty black sand, quartzite and quartzitic sandstone being the predominant rocks. In the Dsawoe Valley most of the streams gave abundant black sand. In this case it is probably derived from the basic crystalline rocks which are so common in the district. Streams from basic intrusions in other places, however, e.g. at Pheto, Achim, and Chai, did not yield much iron ore. In the Nkunya and Kpandu volcanic region also, where the majority of the streams flow over dolerite or basalt outcrops, the amount of black sand was extremely variable, sometimes abundant, sometimes quite scanty.

In the Bismarckburg and Tutukpene region black sand is not as a general rule abundant. The Kalabo and Tolo Rivers, however, east of Bismarckburg, yielded abundant magnetite, and the Gajale, at Chirina, also gave much black sand. A stream between Chai and Bantibo gave abundant magnetite, although no other stream in the neighbourhood gave more than a very small amount, and many of them none at all. In the Oti region black sand is very scanty, except in the case of the Oti River itself, which gave a large amount. This is probably not derived from rocks of the Oti series, however.

Rutile.—This mineral is a fairly constant associate of the zircon in the concentrates, but usually in much smaller amount. In form it is similar to zircon, but crystals with well-developed terminations are rare. They are generally somewhat rounded. Angular fragments and rounded grains are also common. The colour is generally

amber yellow to brown. Inclusions are not common and zoning is rare. Geniculate twins are common in some few concentrates. East of the Togo Range the Todshi River yielded quite large dark brown, nearly opaque fragments which were at first thought to be possibly cassiterite, but the distinct cleavage negatived this. In the Bomboin River, south of Kpatave, the rutile equals the zircon in amount. In many concentrates from the Dayi Plateau also rutile is relatively abundant as compared with zircon. In the Togo Range south of Misahöhe the Aflabo River between Amedzofe and Kpoeta yielded very dark brown crystals, and the streams east of Amedzofe gave dark red ones. The Labo and Sangoa Rivers, in the Dsawoe Valley, gave dark brown rutiles. The mineral is well represented in the Adele Highlands, especially in the Kalabo and Tolo Rivers. The Wulubong and Kente Rivers, flowing from the Tutukpene Range, gave rutile of a darker tinge than usual. The Dijebu River gave large fragments. Dark, nearly opaque grains, associated with much magnetite, are found in a stream between Chai and Bantibo, and dark reddish-brown rutile was got from the stream flowing from the Achim intrusion. The mineral is very constant in its occurrence in the Dayi Valley. In the Konsu River it is in more stumpy prisms than usual, whilst in the Kole River at Kolenu and in the Ajamono River north of Dukluja long needles are found. This is not common. A stream north of Lolobi yielded large dark grains. The mineral is also found in practically every concentrate from the Oti Basin. Here it is often more rounded than the associated zircon. Every variety was got in the Oti River at Otisu, pale yellow to nearly opaque reddish brown, and very slender needles to stumpy prisms. The same river at Sambul gave dark, chiefly rounded grains.

Schorl.—This mineral is very commonly found throughout the country, and it is impossible to assign any particular variety of it to any definite formation or region. It usually occurs in short, roughly rectangular fragments, but sometimes in rounded grains, and more rarely in long laths. In a few cases it shows crystal outlines. The colour is in most cases pale grey. Brown, pink, red, and green varieties are not rare, however.

Garnet.—The only kind found in the concentrates was the pale, cinnamon to pink coloured almandite variety. It is always in angular fragments owing to its brittleness and lack of cleavage, and is practically in every case clear and without inclusions. Other kinds of garnet are probably too subject to decomposition to exist in concentrates. For instance, in a stream 2 miles south of Tokwe, though the only garnet found on panning was scanty almandite, yet the stream bed contained numerous large garnets. These seem from their distinct non-isotropic character to be of an iron-lime garnet type. They are much decomposed, however, and could not long survive the attrition to which they would be subjected in an ordinary stream channel.

Garnet is common in the streams on the east side of the Togo Range south of Misahöhe, since these drain garnetiferous amphibolite areas. North of Misahöhe, however, practically none was found. It occurs scantily in quite a number of streams in the Togo Range south of Misahöhe, but was not found on the Dayi Plateau, nor on the Bismarckburg and Tutukpene region except in one instance. In the Dayi Valley garnet was only met with on the east side of the Nkunya Range and east of Vakpo. It was hardly seen at all in the Nkunya and Kpandu volcanic area or in the Oti region. In the Oti River itself, however, the mineral is very common, especially in the higher parts of its course, and varies in tint from colourless through pale cinnamon to pink. The Volta River in nearly every case yielded abundant cinnamon to pink-coloured fragments.

Epidote.—Angular cleavage fragments are most common, with distinct pleochroism. There is not much variety in type shown by this mineral. It is common along the east side of the Togo Range, especially south of Misahöhe in streams flowing over the crystalline metamorphic rocks. It appears scantily in many concentrates from the Togo Range south of Misahöhe and also in some from the Dayi Plateau. It is rare in the Bismarckburg and Tutukpene Highlands. It is common in the Dayi River, but rare elsewhere in the Dayi Valley. Many of the streams flowing over the Nkunya and Kpandu volcanic rocks yield epidote. None was found in the Oti Basin except in the Volta and Oti Rivers.

Hornblende.—Green hornblende fragments are not abundant in any of the concentrates, but they appear commonly in small amounts along the foot of the Togo Range on its eastern side, and also in the Dsawoe Valley. They are obviously derived from the amphibolites which are so common in these areas. In the Togo Range itself the Aflabo River, between Amedyofe and Kpoeta was the only one to show hornblende. The Dayi Plateau, Bismarckburg Highlands, and Tutukpene Range yielded nil, as also did the Dayi Valley, except for a few in the Odomi River at Borada, in a stream between Kolenu and Deme, and at Abessia. In the volcanic zone only the Ajamono River north of Dukluja gave hornblende, and in this case it may be derived from the Volta gravels. In the Oti River some was found at Otisu and some dark fragments east of Bimbila. Otherwise there is none in the streams of the Oti region. The mineral is common in most of the Volta pannings.

Kyanite.—This mineral usually occurs in clear, colourless cleavage fragments. Only in a few cases is it dark with inclusions. The Efle River, south of Sokode, shows this latter type. Kyanite is found in many of the streams east of the Togo Range and is probably present in most of them, especially those flowing over the crystalline metamorphic rocks. None was found in the streams of the Togo Range, but it is common in the Dsawoe Valley. It is scanty in the Bismarckburg Highlands and absent in the Tutukpene

Range. The Dayi Valley yielded very little, and none was found in the Buem volcanic area. It is common in the Oti River, but none was found elsewhere in the Oti region except in a tributary of the Tupe River, which probably flows over crystalline rocks in its upper reaches. The Volta yielded it in several instances, but not invariably.

Pyroxene.—This is not common. It was only got abundantly in streams in the vicinity of pyroxenite intrusions, e.g. in the Efle River, south of Sokode, near which large fragments of pyroxenite were found, and at Pheto, north of Akata. The former gave hypersthene, the latter both hypersthene and diallage. Its appearance in large quantity in the Wuta River in the hills west of Tokwe, both in rhombic and monoclinic varieties, makes it almost certain that there is a pyroxenite intrusion higher up the stream bed. In the Nkunya and Kpandu volcanic area augite was only found in a very few instances, although in many cases the streams flow over pyroxene-bearing rocks. In other parts of the country it was not found.

Staurolite.—This mineral is quite uncommon. In the country east of the Togo Range it occurs fairly frequently in small amounts, otherwise only very rarely was a fragment or two found. It is usually in fairly clear angular fragments free from inclusions, but sometimes rather dark and cloudy with inclusions. Its rarity is in keeping with the general absence throughout the country of intrusions which have produced much contact metamorphism.

Spinel, *Monazite*, *Brookite*, and *Anatase* were found in one or two instances, but are quite rare. *Gold* occurs in places, but only very scantily.

Distribution of Concentrate Types.

The examination of the concentrates leads to the conclusion that a typical assemblage of minerals can be assigned to each of the chief geological formations, and the presence of this assemblage gives a strong indication of the presence of the corresponding formation in the drainage area of the stream in which it is found. These assemblages are as shown in the table below.

One interesting point shown by the table is the distribution of the different types of zircon crystals. It is curious that the pink and purple types should be so characteristic of the Togo series over such a wide area, whilst so uncommon both in the younger Buem and the Oti rocks and also in the more highly metamorphosed older rocks. The idea which most readily suggests itself is that the zircons are affected by the degree of metamorphism to which the rock has been subjected. A certain support is lent to this by the rather common occurrence of pink zircons in the more highly altered Buem rocks of the Tutukpene Range, whilst they are practically absent in the Dayi Valley and in the Oti district. If the colour is due to the presence of ferric oxide, as stated by Miers (*Mineralogy*, p. 509), then it is possible that colourless crystals in the unaltered argillaceous, and usually to a certain extent ferruginous, sediments might during

Crystalline Metamorphic Series.	Plentiful, colourless, chiefly clear, but often cloudy with inclusions.	Common, but variable in amount.	Common.	Uncommon.	Common.	Common, frequently abundant.	Fairly common.	Usually present in small amount.	Concentrates as a rule plentiful. Staurolite not uncommon.
Togo Series.	Plentiful. The majority small, colourless, and clear, but pink ones almost invariably present, and in most cases also the darker pleochroic variety.	Common, but not abundant.	Common.	Common.	Rare.	Uncommon.	Practically absent.	Absent, except in the Adele Highlands, where it is not common.	—
Buem Series. — Tutukpene Range.	Not very plentiful, colourless, clear. Sometimes a few pink ones.	Scanty.	Common.	Common.	Absent.	Scanty.	Absent.	Absent.	—
Buem Series. — Dayi Valley.	Not very plentiful. Small, chiefly colourless and clear. Coloured crystals rare.	Scanty.	Plentiful, both as crystals and rounded grains.	Fairly common.	Rare.	Rare.	Very rare.	Very rare.	Concentrates usually scanty.
Buem Series. — Nkunya and Kpandu Volcanic Area.	Scanty. Crystals frequently zoned.	Variable in amount.	Common.	Fairly common.	Practically absent.	Fairly common in places.	Practically absent.	Absent.	Concentrates very scanty.
Oti Series.	Fair in amount, chiefly clear and colourless. Yellow to yellowish-green crystals, very typical and rare elsewhere.	Rare.	Common.	Common.	Absent.	Absent.	Absent.	Absent.	Concentrates usually scanty.

regional metamorphic action become coloured. In the case of rocks more highly altered, and often completely recrystallized, such as occur in the crystalline metamorphic series, it is more likely that the metamorphic forces at work would tend to recrystallize and purify the existing zircon.

The iron-stained zoned crystals common in the Buem volcanic area appear probably due to the crystallization of the mineral in, or in close communication with, basaltic intrusive or volcanic rocks. The presence of much iron would tend to show up clearly the different stages in the growth of the crystal by the deposition of a film of oxide at each pause in the process.

It will be seen from the table that the assemblage from the Tutukpene range is intermediate in character, especially as regards the zircons, between those of the Togo Range and the Dayi Valley. This is probably due, as suggested above, to the rather greater metamorphism of the Tutukpene Range rocks as compared with those of the Buem series in general.

The Oti and Volta Rivers drain regions containing so many types of rock that the concentrates from them are of a more generalized type than those from the smaller streams. Garnet is invariably present, and kyanite also is very common, whilst in the Volta staurolite is usually found. The head waters of the Oti River flow over crystalline rocks in the French territory farther north, where the Oti rocks have been removed by denudation, and probably the thickness of the Oti series in the north of the Yendi district is not great. This accounts for the abundance of metamorphic minerals in the sands of the Oti River at Sambul and east of Bimbila, and also in the Tupe River.

A System of Basic Intrusions at the Northern End of the Island of Sark.

By S. W. Wooldridge, B.Sc., F.G.S., and H. W. Cornes.

A RECENT investigation of the igneous rocks of Sark revealed the presence of an interesting series of basic intrusions particularly well exposed near the northern extremity of the island. Some of the phenomena there seen seem to be identical with those described by Harker from the Isle of Muck in rocks of widely different age, and they throw some light upon the mechanics of intrusion.

At a point known as the Eperquerie there is a steep descent to the shore, where low-lying rocks run out in a north-easterly direction, forming a well-marked promontory. Into the gneissose rocks which form the promontory, a series of basic intrusions is seen to have forced its way, some of the intrusive bodies being dykes, while others are of a dome-like form.

The dykes are apparently of two ages and are certainly younger than the schistose rocks which overlie the gneiss over the greater part of the island. The most striking is about 3 feet in width and

bears roughly N.–S., though following a markedly sinuous course ("A" on the map, Fig. 1). The rock shows a well developed and very regular columnar jointing, giving the effect of a series of tilted steps (Fig. 2). The dyke terminates abruptly northward in a small knob or boss ("B") which is surrounded on all sides by gneiss.

A small dyke ("C") is seen to cross the first, running roughly E.–W. Its outcrop is seen to be interrupted, but it resumes in a parallel course a few yards to the north. Harker describes similar cases from Muck, and remarks: "Doubtless a section at a lower level would make the real continuity apparent" [1] (Fig. 4).

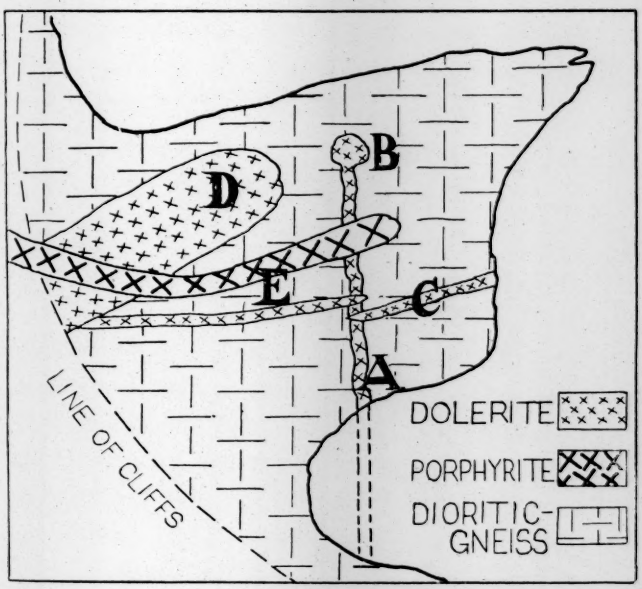

FIG. 1.—Sketch-map (diagrammatical) of the Eperquerie Promontory.

Nearer the cliffs a dome-like mass of dolerite ("D") is found, the gneissose country rock surrounding it on all sides and in places resting upon it. The shape as seen in plan is elliptical with the longer axis, trending N.E.–S.W. Traced back into the cliff, this body is seen in section, when the dome-like habit is clearly displayed, the upper boundary tending to follow curved joints in the enclosing gneiss.

In the cliffs to the east and west of the Eperquerie a number of similar dolerite domes is seen, one of them broken by a fault (Figs. 3 and 5). To give some idea of the dimensions it may be noted that the width of this body at beach level is about 30 feet, while it rises more than 20 feet above the beach at its highest point.

[1] *The Natural History of Igneous Rocks*, 1909, p. 75.

All the intrusions so far described are, petrographically, somewhat featureless. They may be described as much altered dolerites of granulitic texture. The only unusual character is the occurrence of primary biotite in them.

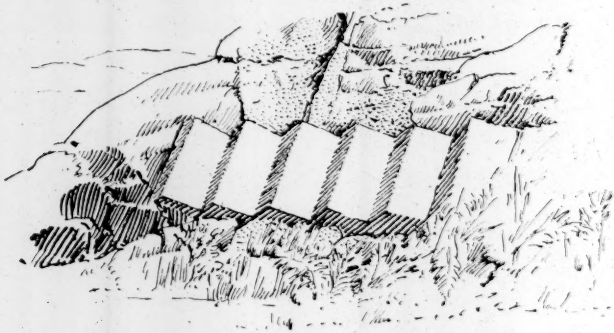

FIG. 2—Dyke showing columnar jointing.

FIG. 3.—Dome-like intrusion of dolerite in gneiss.

The last intrusion to be noted is a thick dyke (" E "), 8 feet wide, of a porphyritic rock which cuts across the dome (" D ") in an arcuate curve. Westward it may be traced into the cliff, while eastward it plunges beneath the gneiss and its further course is uncertain.

The petrographical character of the rock may be briefly noted. In the hand specimen it shows greenish phenocrysts of felspar

up to $\frac{1}{4}$ in. in length set in a fine-grained black groundmass. Microscopic examination shows it to be a relatively basic granophyre having affinity with the markfieldite or granodolerite types. Much altered phenocrysts of plagioclase, rounded by corrosion, are set

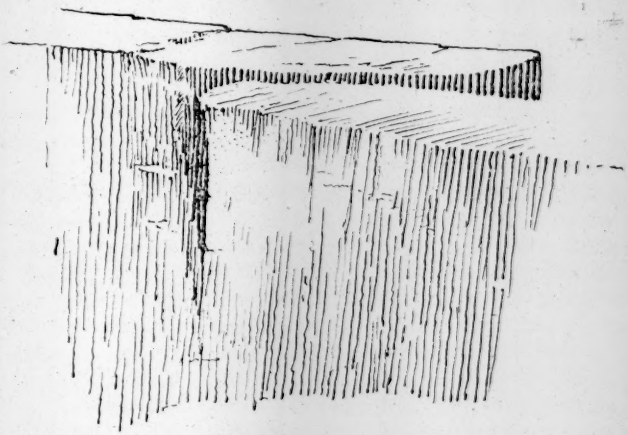

FIG. 4.—Diagrammatic sketch of dyke showing discontinuous top.

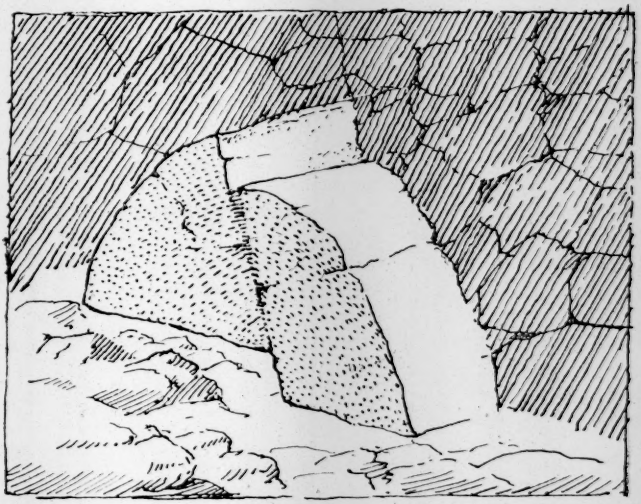

FIG. 5.—Dome-like intrusion of dolerite in gneiss broken by a fault.

in a groundmass largely composed of small zoned plagioclase crystals of good form and delicate interstitial micropegmatite. The original mafic constituents are represented by chloritic and actinolitic alteration products, and it is clear that much of the chlorite is

secondary after biotite. The alteration of the felspar makes it impossible to determine its composition, and hence it is difficult to name the rocks precisely. It will be referred to in the sequel as a granodolerite.

In attempting to account for the somewhat unusual form of the intrusive bodies, two significant factors in the problem are (1) the nature of the country rock, and (2) the petrographical character of the intrusions.

As regards the first factor, it is apparent that the dioritic gneiss must be a singularly impenetrable rock in its relation to intrusions, being without regular divisional planes of any kind. It is true that it is slightly foliated, but the foliation planes are much too ill-defined to serve as directions of easy passage. The small scale jointing is on a polygonal plan and shows no relation to the intrusions. Indeed, the only divisional planes which are likely to have affected the form or extent of the intrusions are certain curvilinear joints. These joints, though sporadic in distribution, may be traced in some cases for hundreds of yards, and are very characteristic of the dioritic gneisses of the Channel Islands. They may be picked out in the cliffs of Herm from the deck of a steamer half a mile away.

There can be little doubt that the granodolerite dyke has followed such a joint in its passage through the gneiss, and its curved form is thus explained. The sinuous course of the dyke " A " seems also to have been determined by similar though smaller joints. Its abrupt termination is interesting. The total length of the dyke is unknown, but it undoubtedly has a long course through the schistose rocks of the island. The mass of relatively inpenetrable gneiss appears to have arrested its northward progress. The idea of a lateral as well as a vertical propagation of a dyke is no new one, appearing as long ago as 1835 in the writings of Hopkins.[1] In the case now recorded the suggestion is clearly conveyed that the dyke " wormed " its way into the gneiss for a short distance before giving up the attempt at further northward progress. In this connexion one recalls the case described by Harker from Skye where dolerite dykes end abruptly with swollen terminations against an agglomerate neck.[2]

It has already been noted that the upper surface of the intrusive domes shows a parallelism to the curved joints. Nowhere is a good exposure of the base of one of these bodies to be seen, but it may be anticipated that a similar relation to the jointing would be found to hold. It would appear, indeed, that the doleritic magma was injected into phacoidal cavities bounded by joints. The formation of such cavities implies a different distribution of stress to that which gave rise to the dykes, but the order in time of the two intrusive phases has not yet been clearly made out.

[1] *Trans. Camb. Phil. Soc.*, vol. vi, 1835, p. 69.

[2] " The Tertiary Igneous Rocks of Skye " : *Mem. Geol. Surv.*, 1904, p. 293.

It is not possible to deal exhaustively with the second factor—the petrographic nature of the intrusive rocks. Harker has remarked upon the irregular behaviour of certain dykes in Muck, stating that " they (the irregularities) also depend in part on the petrographical type, being found less in ordinary basalts and dolerites than in certain special rocks richer in alkalis ".[1] It is, therefore, interesting to note that the Sark intrusions frequently show a slightly alkaline character which is reflected in the presence of biotite. In certain dykes in the gneiss tract of Little Sark the biotite is accompanied by small amounts of titan-augite.

It is suggested that the alkaline character of the rocks, and especially the presence of biotite, may be attributed to a high flux content which permitted reactions analogous to hydrolysis with consequent breakdown of the meta-silicate molecules to the ortho-silicate condition. A high content of volatile fluxes would also imply reduced viscosity, and it may well have been in virtue of this fact that the alkaline types were enabled to penetrate the gneiss. The fact that the normal ophitic dolerites and mica-traps of the island are notably absent in the areas of gneiss lends support to this supposition.

In conclusion, the authors desire to thank Dr. G. H. Plymen, with whom they visited the island, and to whose detailed knowledge of the locality they are greatly indebted.

Notes on the Formation of Lateritoid in N. Rhodesia.

By R. Murray-Hughes.

IN this paper no new theory is offered as to the formation of those rocks, found in so many places in the Tropics, known as laterites and lateritoids. Rather is it offered as confirmatory evidence of the hypothesis, which has been put forward by several writers (5),[2] that in general they are formed by the evaporation of iron-bearing waters as they are brought to the surface by one or more causes, such as capillarity and hydrostatic pressure. The part that animal life may play in the deposition of the iron, as well as in the solution of it, does not appear, however, to have been noted (5).

The writer prefers to confine the term " laterite " to those deposits that are derived from the alteration of a formation directly underlying them as compared with those that have been formed by solutions, the source of which may lie in distant and dissimilar " country " to that over which the ironstone rests : for these he reserves the term " lateritoid ".

An exceptional opportunity was offered recently to study the formation of lateritoid during a traverse taken along the right bank of the Kafue River between Long. 26° 50′ E. and 27°. In this particular

[1] " Geol. of the Small Isles of Inverness " : *Mem. Geol. Surv.*, 1908, pp. 150–1.

[2] Numbers in parentheses refer to Bibliography at end of paper.

area, hills of ferruginous mica-sandstone and a belt of hematite-schist run in a course parallel to that of the river, some 7 miles back from it. Hematite occurs also as veins and disseminated grains in the sandstone. This last is cleaved and porous, and these features allow of a thorough leaching by surface waters. Locally, the seasonal rainfall will average 45 in., and it falls between the months of October and March.

From these hills the surface has a gradual drop to a point 4 miles closer to the river, where the lateritoid makes its first appearance. Then follows a plateau, 3 miles wide, covered almost completely by that rock. The plateau is quite thickly wooded, and there is no lack of vegetation. The topography is young, and streams are now cutting back into the lateritoid and underlying clay, with the formation of lateritite, as defined by Fermor (4).

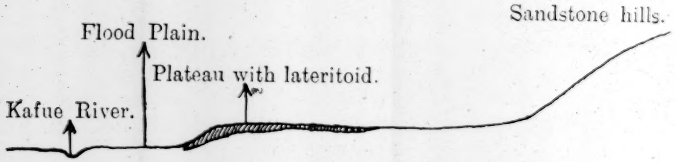

FIG. 1.—Generalized section across the country bordering the Kafue River, N. Rhodesia. Horizontal scale, $\frac{1}{2}$ in. = 1 mile; vertical scale, greatly exaggerated.

Where the plateau abuts on to the flood plain, which stretches out on either side of the river for $\frac{1}{2}$ to $\frac{3}{4}$ mile, the lateritoid terminates abruptly. The flood plains, as well as the higher ground, are covered in the customary fashion by quantities of " ant-hills ", cone-shaped cellular structures varying from 6 ins. to 10 ft. in height, and, on the plateau, the alteration of these to lateritoid may be observed at a thousand different stages; from a mere dark stain around the sides of the nest, to the solid ironstone showing no trace of its origin.

It is the opinion of the writer that the circulating water, with its load of iron derived from the sandstone hills, on its way down to the lower-lying country following the Kafue, was checked in its passage by the clay of the flood plain. Hydrostatic power forced it to the surface, and capillary action carried it up and through the ant heaps. With their cell-like structure, these would act as perfect evaporating towers and the iron would be precipitated.

To discover whether a similar deposition was taking place to the north of the hills, these were crossed at a point named Lufuka. The view obtained was well worth the journey. Encircled by towering hills, a smouldering lake was seen, estimated to be 2 miles long by 1 mile wide. First a lake, and then a swamp, the now marooned peat, which must be of great depth, is slowly burning away.

The local natives aver that the rains do not extinguish the fires,

and that they have been burning for several years. They live in great fear of them, and are quick to warn visitors of the treacherous nature of the innocent-looking ash-covered ground. It appears that more than one has come to a terrible end by sinking through the soft ash, presumably to the fire below. The smoke makes its appearance evidently at those places where the fire is close to the surface.

Towards the higher parts of this old lake, a most solid-looking body of limestone outcrops. It contains abundant shells of common *Helix*, which are common in the incoherent soils of the vleis. On close investigation, it is surprising to find that the rock lies simply as flat cakes on the loose soil. "Sinter" does not suggest the structure, but most travellers will appreciate its form if I use the term "calcareous lateritoid".

The iron variety was not found.

The features described above, together with the fact that many raised river courses were noticed, point to a relative lowering of the water-table in the area under consideration, and this undoubtedly has aided in the formation of the lateritoids.

Sable Antelope Mine,
via Mumbwa, N. Rhodesia.
8th December, 1922.

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Cambrian Fossils from the Dead Sea.

By W. B. R. King, M.A., F.G.S.

THE fossils described below were collected by Messrs. B. K. N. Wyllie, Keir A. Campbell, and G. M. Lees, working on behalf of the Turkish Petroleum Company, who have kindly made arrangements for me to investigate their collection, which proves to be of some interest.

Cambrian fossils have been recorded from this area by Blanckenhorn (1) [1] in 1910 and Dienemann (2) in 1915, but their material seems to have been meagre and to have come from localities near the southern end of the Dead Sea. The localities from which the fossils were collected by Mr. Campbell are shown on the accompanying sketch-map (Fig. 1).

[1] Figures in parentheses refer to Bibliography at end of paper.

The lithology and fossil contents of the rocks from the four localities are as follows :—

(λ_1) South bank of Wadi Sarmuj. Hard white dolomite, in places somewhat cavernous and showing specks of copper carbonate. The fossils weather out on the surface, but the shells are considerably

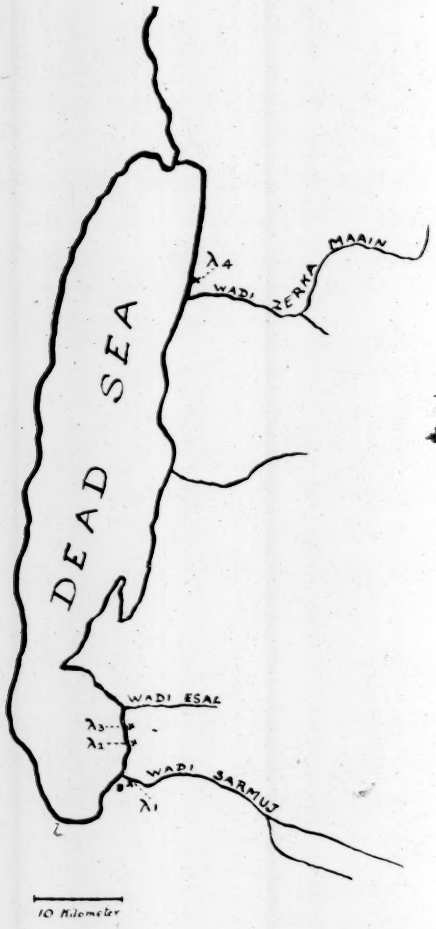


FIG. 1.—Sketch-map of the Dead Sea showing Cambrian fossil localities.

thickened by secondary mineral changes. Only two species of brachiopoda are from this locality, viz. *Siphonotreta* (?) and *Micrometra* (*Paterina*) *alata* sp. nov. (notes and descriptions of fossils are given below). This may be one of the localities mentioned by Blanckenhorn.

(λ_2) Wadi Kneye (Gineya). Red dolomitized oolitic limestone with *Siphonotreta* (?) and *Hyolithus*.

(λ_3) Wadi Rimeileh (1 mile south of Wadi Esal). A green micaceous mudstone with trilobite remains, mostly broken pleuræ and two pygidia and a free cheek of an asaphid character.

(λ_4) Shore of the Dead Sea, half-mile north of Wadi Zerka Maain. A crystalline limestone band 2 inches thick in the sandstone series (Nubian Sandstone), yielding numerous specimens of *Anomocare campbelli* sp. nov. Other pieces of rock are almost composed of the shells of *Hyolithus* with a few trilobite fragments.

Description of Fossils.

Brachiopoda—Siphonotreta (?).

The most abundant fossil from λ_1 and λ_2 is undoubtedly the form which Dienemann described and figured (2) as *Siphonotreta unguiculata* Eichw (?). Unfortunately the specimens show no internal characters, so that even the generic determination must remain in some doubt. The following points, however, can be made out.

(*a*) A peduncle opening of medium size situated at or just behind the apex of the shell. This opening in section is seen to be somewhat funnel-shaped, being wider externally.

(*b*) The surface of the shell is ornamented with concentric lines of growth, some of which appear to encircle the peduncle opening.

(*c*) Between the concentric growth lines the surface of the shell (usually obliterated by secondary mineral changes) seems to be covered with a fine crossing ornamentation which gives a slight rugosity to the surface. It is somewhat doubtful whether this is original or due to the crystallization of the minerals which replace or thicken the shell.

There are, however, some other points which throw doubt on the generic determination in the absence of internal structures, namely, the absence of any signs of spines on the shell and the large dimensions of the specimens. The normal size of *Siphonotreta* ranges from 3 to 10 mm., while the largest of the specimens from the Dead Sea must have belonged to an individual at least 25 mm. in length. It would seem advisable in the present state of our knowledge concerning the material available to follow Dienemann in referring these forms provisionally to *Siphonotreta*, but it is better not to make the specific determination since the stratigraphical evidence and the rest of the palæontological evidence seems to point to a lower horizon than that at which this genus usually occurs.

Micrometra (*Paterina*) ? *alata* sp. nov. (Fig. 2.)

One specimen of another brachiopod from (λ_1) is preserved in white dolomite and is beautifully weathered out on the surface of the rock. This specimen is referred to the genus *Micrometra* (*Paterina*) with some hesitation, on account of its alate form. The

external characters of one valve only are known. The general outline is semicircular and subconical, its greatest breadth of 10 mm. is at the posterior margin. A minute beak is present which slightly overhangs the triangular fissure of the false area. The opening of the triangular fissure is 90 degrees. There is no sign of a pseudodeltidium. The angle between the surface of the shell and the false area is sharp and slightly less than a right angle. The postero-lateral angles are sharp, being formed by a wing-like extension of the shell to form an angle of about 45 degrees on one side, but only about 60 degrees on the other: this is due to irregularity in growth of the shell.

The ornamentation is by well-marked but fine concentric lines of growth, which show that in the young stages the shell was even more alate than at maturity.

The shell most like this species is *M.* (*Paterina*) *rhodesi* Cobbold (3), since this is an alate *Micrometra*. It differs in the angle of the triangular fissure.

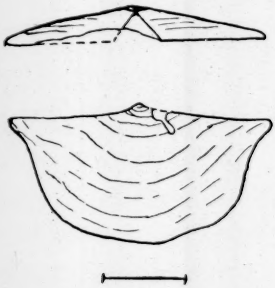


FIG. 2.—*Micrometra* (*Paterina*) ? *alata* sp. nov. × 3.

Walcott (4) does not figure any alate *Micrometra*, but since Cobbold refers the above-mentioned species to this genus, it is not proposed to make a new genus or subgenus on the scanty material available.

With regard to the horizon of *M.* (*Paterina*) *alata*, there is some doubt. Walcott (4) (p. 336) gives a tabulate view of the ranges of the various species of *Micrometra*, and from this it is clear that the majority are either Lower or Middle Cambrian in age, only two species being found in the Upper Cambrian. The forms from Comley (3) (p. 376), with the exception of one in the Middle Cambrian, all belong to the Lower Cambrian.

These two brachiopods from the Dead Sea, therefore, give rather conflicting evidence of age.

Hyolithidæ.

Specimens of *Hyolithus* occur at λ_2 and λ_4. Although the beds may represent somewhat different horizons the forms appear to be similar. The shells are smooth and show no surface ornamentation. They vary in length from 15 to 30 mm., the shorter

being of commoner occurrence. They are straight, gradually tapering and circular in cross section. They would therefore appear to belong to the *Teretes* group of the subgenus *Orthotheca*, as divided up by Holm (5). The shells are rather thick, but this is probably due to secondary deposits of calcite, as in the case of the brachiopods. One specimen shows simple septa crossing the shell rather like those figured by Holm (5) (pl. 1, fig. 24).

The *Teretes* group of *Orthotheca* belongs essentially to the Cambrian.

Trilobita.

(*a*) *Specimens from* λ_3.—The trilobite remains are preserved in a micaceous silt. They consist mainly of flat lying pleuræ, which are produced backwards into a short stout spine. They are markedly grooved with a wide, but shallow, oblique groove. Associated with these fragments are two pygidia and a free cheek. The pygidia are 20 mm. across and almost flat and spatulate in outline. There is a smooth marginal border and a narrow segmented axis. The free cheek is also flat, markedly opisthoparian, and possesses a short stout genal spine. The species is of a distinctly Asaphid type. It might be either Cambrian or Ordovician in age.

(*b*) *Specimens from* (λ_4).—From this locality there are numerous dismembered specimens preserved in sandy crystalline limestone, which are well preserved, but only one species appears to be present.

The generic determination is somewhat doubtful, but the characteristics seem to point to its inclusion in the genus *Anomocare*.

The thick blunt axis of the pygidium and shortness of the posterior margin of the cranidium would appear to preclude its inclusion in Walcott's genus *Anomocarella* (6), although the parallel sided glabella agrees rather better with that genus. Most species both of *Anomocare* and *Anomocarella* have a conspicuous frontal rim separated from the glabella by a marked flat area, but in this species the frontal rim is inconspicuous and is only seen on specimens showing the internal cast of the cranidium.

It is suggested, therefore, that this species belongs to a rather advanced development of the *Anomocare*, in which the relief of the various parts of the cranidium are being merged into smooth contours. This is borne out by one smaller glabella, presumably of a young individual, in which the features of the glabella stand out more clearly than in the fully grown forms.

Anomocare campbelli sp. nov. (Figs. 3 and 4*a*, *b*.)

Head-shield.—The cranidium is nearly circular in outline, the general shape is a portion of a sphere, the surface is almost smooth, and the features are only seen on the inner side of the test or on decorticated specimens. The glabella is one-third the width of the cranidium. It is very faintly marked off, slightly tapering anteriorly, but swollen slightly at the anterior end at the junction with the ocular ridge, thus giving the glabella the appearance of being nearly parallel-sided. There are faint traces of four glabellar furrows, of

which the basal one is curved slightly posteriorly ; the anterior ones are slightly inclined anteriorly, all reaching about one-third across the glabella. The fixed cheeks are smooth and rather broad, the eye-lobe is small and flat, situated opposite the centre of the glabella, the cheek falling away rather rapidly on the posterior side of the eye-lobe. The ocular ridge is faint, curving from the anterior end of the eye-lobe to the antero-lateral angle of the glabella, which is slightly expanded laterally to meet it. The frontal limb and frontal rim are both of nearly constant width, equal to half that of the glabella or one-third of the total length of the cranidium. The frontal rim is narrow, scarcely defined from the frontal limb, the whole curving down in general conformity with the spheroidal contour of the cranidium. The inner surface of the frontal limb shows faint radiating wavy vein-like markings on some specimens. The neck segment is not very clearly marked off, but it possesses a marked small protuberance on the under surface of the test on each side of the axial ring. The surface of the axial ring is ornamented with a few wavy lines.

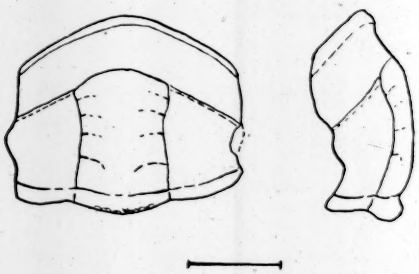


FIG. 3.—*Anomocare campbelli* sp. nov. Cephalon, front and side view. × 2½.

Free cheeks are associated with the cranidia, but none is complete. The free cheek is produced into a long genal spine, equal in length to that of the cranidium. This spine appears to be somewhat oval in cross section, and to be hollow. Its surface is ornamented by longitudinal lines.

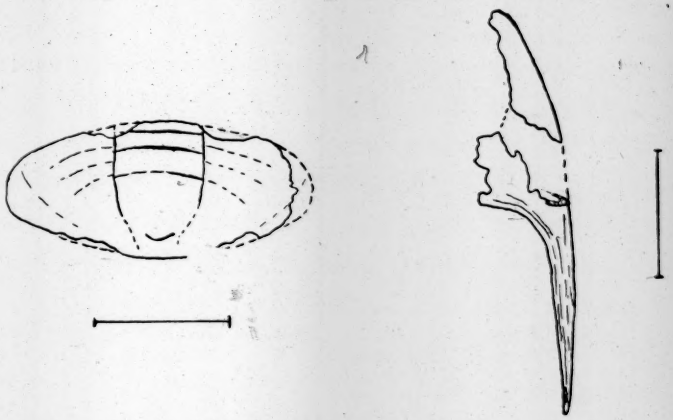
Thorax.—The number of segments is unknown. The axis is convex, its width is only slightly less than that of the pleuræ. There is a slight knob on the under surface of the test where the axis joins the pleuræ. The pleura is flat for two-thirds of its length, the marginal one-third is turned downwards and slightly backwards. There is a marked pleural groove beginning close to the end of the pleura and fading away about half way to the axis.

Pygidium.—A number of pygidia are associated with the cranidia. The width of the pygidium is twice its length, the axis is broad and strongly arched, it shows three rings and ends bluntly in a smooth portion, which does not reach to the margin. The pleural part gently

convex, and faintly divided by three or four grooves, surrounded by a smooth flat border which is a gentle curve in the posterior part, but turns up rather suddenly with a slight sigmoidal curve near the anterior angles. The surface of all parts of the pygidium is smooth.

Dimensions of the types are : Cranidium, length 9·5 mm., breadth 12 mm. ; free cheek, total length 17·5 mm., length of spine 9 mm. ; pygidium, length 8·5 mm., breadth 20 mm. [Note.—The above specimens belong to different individuals.]

Anomocare is a genus with a world-wide distribution and occurs almost always in the Middle Cambrian. The Sardinian Cambrian is one of the nearest Cambrian localities for which fossils have been described. Bornemann (7) figures one species doubtfully referred to this genus, but it shows no characteristics in common with the Dead Sea specimens. A few species are also described from the



4*a*. 4*b*.

FIG. 4.—*Anomocare campbelli*, sp. nov. 4*a*. Pygidium. × 2½.
4*b*. Free cheek. × 3.

Indian Cambrian by Reed and others, but these again have nothing in common with the new species. China, Siberia, and Indo-China produce innumerable species of this genus, which have been described by Dames, Schmidt, von Toll, Mansuy, and, particularly, Walcott (6), who describes thirty-four species of *Anomocare* with the allied genus *Anomocarella* ; but out of all this described material no form is quite so smooth and with such a small inconspicuous frontal rim as the Dead Sea species. It therefore seems rather strange that the form most like the specimens from the Dead Sea is that described by Cobbold (8) from the Protolenus beds of Comley, under the name *Anomocare platycephalum*. This species, as the name implies, is flat rather than spheroidal, and the chief resemblance is a rather superficial one, namely that the glabella and frontal rim are faintly marked off, a feature which is likely to develop at different times in the evolution of the different stocks.

The trilobite recorded, but not figured, by Blanckenhorn (1) from the Dead Sea area as a *Ptychoparia*, with some characters which suggest *Protolenus*, may be the species under discussion, but the information given is not sufficient to make a comparison.

The general impression given by this species is that it is a Middle Cambrian type, but since it is new it cannot be used to give a more exact correlation with other areas. All the evidence at present available, however, tends towards the establishment of the Cambrian (probably Middle Cambrian) age of a considerable thickness of strata on the east of the Dead Sea, including part of the Sandstone series referred to the Nubian Sandstone.

These strata must have been laid down during the Cambrian transgression on to the old land surface, but since all the genera in this collection have a world-wide distribution no evidence of the palæozoological province is forthcoming from their study. More reliance from this point of view must be given to the identification of Paradoxides (1). This would appear to indicate that these exposures form a link in the chain of evidence for the continuation of the Southern European Cambrian sea to the east, as suggested by Dienemann (2), but the data at present available does not seem to justify even the suggestion that this Cambrian sea spread further east to join that of Northern India.

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Note.—The specimens are preserved in the Sedgwick Museum, Cambridge.

The Hirnant Beds and the Base of the Valentian.

By O. T. Jones, M.A., D.Sc., Professor of Geology, Victoria University, Manchester.

RECENTLY I had an opportunity of paying a brief visit to the localities described by Miss Elles [1] as affording a clue to the horizon of the Hirnant Beds. As I have for many years believed that the fauna of the Hirnant Beds is Ordovician, I was anxious to see upon what evidence the assignment of those beds to the Silurian was based. The Bwlch-y-groes locality was visited with Professor W. J. Pugh, University College of Wales, Aberystwyth, who will shortly deal with the structure of that area. It is sufficient

[1] *Quart. Journ. Geol. Soc.*, vol. lxxviii, 1922, p. 132 (Bwlch-yr-Hwch), and Geol. Mag., Vol. LIX, 1922, p. 409 (Bwlch-yr-Hwch and Bwlch-y-groes).

for the present to state that this section has been misinterpreted by Miss Elles, and so far from proving that the Hirnant Beds lie within the Valentian, shows, if anything, that they cannot possibly form part of that series, which is fully represented there and has much the same characters as throughout Central Wales. To anyone thoroughly familiar with the Ordovician-Silurian succession of Central Wales, the structure and rock-succession of the Bwlch-y-groes Pass presents no difficulty and it certainly gives no support to the idea that the Hirnant Beds are of Lower Valentian age.

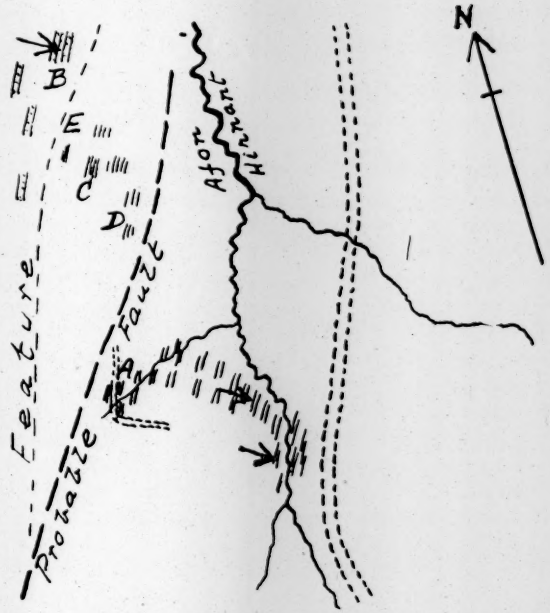

FIG. 1.—Sketch-map of the head of Cwm Hirnant. Scale, approximately 6 inches to the mile.

Two days later I visited the section at Bwlch-yr-Hwch in the Hirnant Valley, but unfortunately I did not take with me copies of Miss Elles's papers, in which this section is described. As Bwlch-yr-Hwch is not marked on the 1 in. Ordnance maps, the only clue to its position that I could remember was the statement (GEOL. MAG., p. 411) that the Bwlch-y-groes section is 2½ miles to the south (actually it is nearer 5 miles). Accordingly I judged it to be the gap known locally as the Hirnant Pass at the head of Cwm Hirnant, which lies at approximately that distance from Bwlch-y-groes. It soon became evident that this could not be the section described, but as the rocks appeared to be almost continuously exposed, it seemed worth a cursory examination.

The head of Cwm Hirnant (Fig. 1) is an amphitheatre bounded by

steep slopes with abundant rock-exposures. The road over the pass climbs the eastern slope. At the head of the valley on the eastern side there is a small gully just below the road and another near the western side. The rocks along the road and between the two gullies are blue-grey, slightly iron-stained slaty rocks, dipping at high angles to the east. They obviously belong to the Gala or Upper Valentian (Tarannon Shales of Dame E. Shakespear). At the point where the western stream leaves the peaty swamp above, there is a conspicuous path on which at a few yards west of the stream (*A* in Fig. 1) I found several specimens of *Monograptus marri* and *M. nudus*, thus confirming the impression of the age of the rocks derived from their lithological characters.

From the path the ground rises to a feature following the western slope and overlooked by massive grey sandy mudstones which are well exposed on a long dip-slope (*B*) about 300 yards to the northward. These correspond apparently to the *Phacops mucronatus* mudstones, or perhaps the top of the Moelfryn Sandstones. They are overlain by a few feet of greyish mudstones (*E*) containing a small *Dalmanella* sp., and these by about 50 to 100 feet of soft dark-blue mudstones (*C* and *D*), identical in lithological character with strata that overlie the *Phacops mucronatus* mudstones in Central Wales and underlie everywhere the zone of *Glyptograptus persculptus*, which I have taken as the basal zone of the Valentian. At this locality these Upper Ordovician mudstones are brought within a few feet of some part of the Upper Valentian. The missing strata include at least 100 feet of Ordovician, the whole of the Lower Valentian, which is present about 3 miles to the south and amounting to about 400 feet, and an unknown thickness, possibly some hundreds of feet, of Upper Valentian. The only explanation which seems adequate to explain this relation is that the missing beds have been cut out by a powerful strike-fault, which ranges down Cwm Hirnant. There is nothing here which corresponds exactly in lithological type to the Hirnant Shales which I afterwards examined, unless it be the grey mudstones with *Dalmanella*. The overlying dark-blue mudstones which elsewhere form the upper part of the Ordovician contain near the base a shaly graptolitic band (*C*) ; the fossils, which are ill-preserved, include *Orthograptus* sp. and *Climacograptus* cf. *miserabilis*, but the band is worthy of further examination. Descending the valley from the head I recognized the Bwlch-yr-Hwch section, and spent some time in examining it and the Hirnant limestone. The Hirnant Shales adjoining the limestone are unlike anything with which I am familiar in the more southerly parts of Central Wales, but lithologically they look as if they might be a development of the beds immediately overlying the *Phacops mucronatus* beds, and this appears, in fact, to be the position of the Hirnant fauna at Conway and at Ashgill in the Lake District. If this is so, then the Hirnant Beds are not even at the top of the Ordovician, but lie well within that system, since the shales farther south form a well-defined group which everywhere

underlie the zone of *G. persculptus*. In the Plynlimon district the position of the zone of *P. mucronatus* is approximately at the base of the group that I termed the Drosgol group,[1] thus lying some 2,400 feet down in the Ordovician. That being generally the position of the Hirnant Beds, the section on the east side of the dry valley referred to on Miss Elles' section (*Quart. Journ. Geol. Soc.*, p. 156, fig. 8) is all the more surprising. It is one of the most perplexing sections that I have ever examined (Fig. 2). The southern end of the dry valley is crossed by a stone wall south of which there are exposures of rubbly greyish-blue mudstones, which, as Miss Elles records, are similar lithologically to certain beds near the Hirnant limestone on the slope to the south. Similar beds are again visible immediately north of the wall, and in these at a distance of about 15 yards (*A*) I obtained *Strophomena siluriana*—a characteristic fossil of the Hirnant Shales.

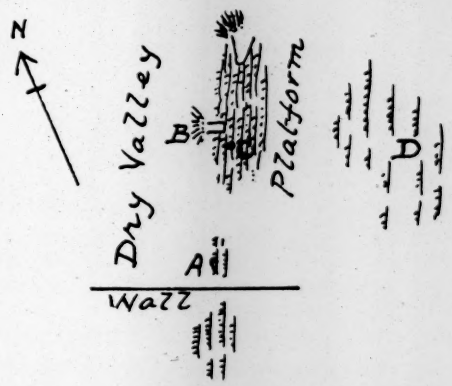

FIG. 2.—Sketch-map of dry valley near Bwlch-yr-Hwch. Scale, approximately 50 yards to the inch.

A narrow belt in which no rock is visible separates them from exposures of slaty rocks to the north, in which several small quarries have been excavated, and taking these exposures together they afford an apparently unbroken succession across the beds. The lowest rocks are rubbly grey mudstones, closely similar to those near the wall; they are succeeded by blue slaty beds of Upper Valentian aspect, and containing a few large calcareous nodules. A narrow vertical cutting (*B*) traverses the grey mudstones into the overlying slaty beds, and I could find no interruption of the succession. In one of the lowest of the slaty bands (*C*), and almost in contact with the underlying grey mudstones, I found some ill-preserved graptolites. Miss Elles records from some part of the succession a suite of graptolites indicative of the *Monograptus Sedgwicki* zone. In view of this it seemed unnecessary to search the slaty beds for fossils; their aspect reminded me either of the uppermost

[1] *Quart. Journ. Geol. Soc.*, vol. lxv, 1909, p. 468.

beds of the Birkhill or basal Upper Valentian. These slaty beds form a narrow platform, which is overlooked on the east by a low slope (*D*) corresponding perhaps to about 100–200 feet of strata. Among the debris derived from this slope, I found a broad *Monograptus nudus*, denoting probably an Upper Valentian horizon.

There is a significant agreement between this section and that at the head of Cwm Hirnant, in that Upper Valentian rocks are brought into juxtaposition with those which elsewhere overlie the *Phacops mucronatus* mudstones. At least 500 feet of strata which are present to the south near Bwlch-y-groes, which are represented also, though by a smaller thickness, at Conway, and so far as I know are never absent in any part of Wales, are wholly missing. There seems no escape from the conclusion that the missing strata have been cut out by strike-faulting. There appear to be at least four alternative explanations of this section.

1. The Hirnant Shales represent a part of the Upper Ordovician and the whole of the Lower Valentian up to the zone of *Monograptus Sedgwicki*. This seems the most obvious conclusion to draw from the sections, though I am convinced it is fallacious. If they occupy this position a comparison with the Ashgill Shales, which contain an almost identical fauna, is clearly beside the point.

2. The Hirnant Shales are separated from the rocks of Valentian aspect by a strike-fault of considerable throw, though I found it impossible to locate such a fault.

3. The shales at the base of the continuous section which resemble the Hirnant Shales, are not, in fact, those shales, but form a part of the Upper Birkhill succession, and are separated by a fault from the shales which contain the Hirnant fauna immediately to the south.

4. The slaty beds which resemble Upper Valentian rocks and contain some graptolites, may, in reality, be a part of the Hirnant Shales, the graptolitic band corresponding, perhaps, to that which I discovered at the head of Cwm Hirnant. On this alternative the strike-fault between them and the *M. sedgwicki* beds recorded by Miss Elles would pass between the platform mentioned above and the foot of the slope to the east. This is probably the most likely explanation.

I would suggest the desirability of making some excavations, with the view of clearing up some of the difficulties presented by this remarkable section.

While attending, this year, the Sedgwick Club Easter excursion to Coniston, under the guidance of Professor Marr, I had an opportunity of examining some of the sections south-west of Coniston at, and near, the base of the Valentian. On revisiting Central Wales I was greatly struck with the lithological resemblance between the Ashgill Shales and the beds which succeed the *Phacops mucronatus* beds in Wales, and I would hazard the opinion that they will ultimately be proved to be of the same age. It is

interesting to note that Marr compared the *Phyllopora hisingeri* band in the Ashgill shales of Backside Beck with similar bands in the Slade rocks of the Haverfordwest district, which occupy an analogous position.

The base of the Valentian in and near Ashgill quarry is very clearly marked, and can be located to within the thickness of a knife-blade. It presents the same sharp contrast as in Central Wales between the structureless Ordovician shales and the overlying well-bedded laminated Valentian shales.

Miss Elles (GEOL. MAG., p. 413) defines the "*Dimorphograptus*" beds of the Lake District which rest on the Ashgill Shales as being equivalent to the zone of *Monograptus cyphus*, but in Appletreeworth Beck the lowest fossiliferous beds yielded me abundant specimens of *Monograptus atavus*, which lies at a considerable distance below the zone of *M. cyphus*, while there is an undetermined thickness of mudstones of Lower Valentian aspect below them. Moreover, Marr has recorded in the same beck and elsewhere the zone of *Cephalograptus acuminatus*. There is reason to believe, therefore, that in some parts of the Lake District the Lower Valentian is fully represented, though I suspect that in other places some of the Lower Valentian has been overlapped. This implies a definite break at the base of that series foreshadowing, perhaps, the incoming of the conglomerate which occupies that position near Austwick. I hope shortly, in conjunction with Mr. T. C. Nicholas, to make a detailed examination of the relation of the base of the Valentian in the Lake District to the underlying rocks.

A Submerged Forest in Bigbury Bay.

By THOMAS WINDER, Assoc.M.Inst.C.E.

THE Memoirs of the Geological Survey (355–6) contain a note of the 1866 exposure of the submerged forest at Thurlestone Sands in Bigbury Bay. This is usually covered by sand and (except between half tide and low tide) by a considerable depth of water. The writer has reported to the Authorities of the Geological Survey a further exposure in March, 1923, which they consider "The best exposure that has ever been visible" and which they desire him to put on record.

On 4th March, it was found that exceptionally heavy weather had removed a large quantity of sand from the eastern edge of the rock platform upon which the famous Thurlestone Rock stands—its removal laid bare a large area of the submerged forest formation. This commenced 90 yards north of the centre line of the fresh-water culvert, which occupies the position marked "Ford" on Devon Sheet CXXXV/8 of the 1906 Edition of the 25-inch Ordnance Map, and extended about 120 yards (measured along its outcrop alongside the Thurlestone-Rock reef) to a point where, at low

water, the formation could still be seen continuing in a north-western direction beneath the water.

At its commencement it measured only 8 feet wide, but expanded to 52 feet just before entering low water, and could be reached down to even further east by driving a spade into the wet sand. It is now entirely buried by a fresh accumulation of sand.

This forest bed rests upon the highly inclined lilac-coloured slate of the reef and dips slightly beneath the sand towards the east. Its eroded outcrop falls towards the north-west at the same rate as does the surface of the reef against which it abuts and upon a slightly lower extension of which it rests.

Its upper layer consists of a greasy, stiff, light-blue clay 15 to 18 inches thick: beneath this is an underclay, from 9 to 12 inches thick, which contains a large admixture of disintegrated silver-coloured slate and coarse sand, both absent in the upper bed. The upper and lower beds contain fragments of sharp *un*eroded quartz (locally known as whiteacre) and flint nodules up to about 3 inches in diameter.

When first exposed there were about a dozen tree trunks from 8 to 15 inches in diameter, lying with their tops towards the west, which, before the eroding of the surface, had been buried in the formation. Three or four large tree roots were apparently where they had grown, and numerous twigs and branches were dispersed through both beds. The remains of the trunks of two trees remained in a vertical position near low water, but were worn down by the action of the water to the surface of the bed; these contained *live* teredo worms in their white calcareous sheaths. Some of the wood near the surface of the beds was in its interior as hard as ebony, but that in the lower beds was soft throughout. There were numerous stalks of leaves and some hazel nuts—one eaten through by the teeth of a squirrel, also some moss.

A few worked flints and a large piece of timber showing human handiwork were found, and are now in the Museum at Plymouth.

About 20 superficial feet of a similar formation was exposed at the same time, about 50 feet west of the sea wall in Inner Hope Cove.

REVIEWS.

THE MOVEMENTS OF THE EARTH'S SURFACE CRUST. By J. JOLY, Sc.D., F.R.S. *Philosophical Magazine*, vol. xlv, 1923, pp. 1167–88.

IN most recent discussions of the tectonics of the earth's crust, insufficient attention is paid to the fundamentally important fact that the major oceanic transgressions and the major continental uplifts, with their concomitant mountain building, are each of world-wide distribution: furthermore, large scale movements of the crust are accompanied by outbreaks of basaltic lava on a vast scale, especially along the western margins of the continents. The doctrine of isostasy in its usual form is scarcely competent to explain these phenomena. In this brilliant paper Professor Joly traces the origin and interrelation of these various events, and especially their marked periodicity, to (1) the existence of a general basaltic magma-ocean, in which the continents float isostatically; (2) the presence of radio-active material in this magma-ocean; (3) the maintenance of isostatic equilibrium of the continents; (4) tidal and precessional movements in the crust.

From measurements of the radioactive content of basalts, it is shown that if the conditions are such that the heat generated is conserved, starting with solid basalt just about at its melting point in the deeper layers of the crust, ultimate fusion of the whole mass is inevitable. This must lead to a decrease of density, with consequent sinking of the continents, accompanied by marine transgression. It is estimated that the latent heat necessary to liquefy basalt would take about 30,000,000 years to accumulate.

When this sub-crustal magma liquefies, great disturbances must be brought about by convectional and tidal currents, and by stoping. When the solid crust above is melted down to a certain thickness, loss of heat becomes rapid and solidification again sets in, and puts a period to the disturbances. But this re-solidification of the magma, with increase of density, must lead to a buoyant effect on the continents with restoration of former relative levels and disappearance of transgressional seas. Altogether it is estimated that 40 to 50 million years are required for the preparation, development, climax, and decadence of a great revolution: of these revolutions four or five are recognized since Algonkian times—the Grand Cañon revolution of some American geologists; the Caledonian; the Appalachian (Armorican of the British Isles); the Laramide of western America (late Cretaceous and early Tertiary), and the Alpine. (This classification, it may be noted, seems to imply an enormous lapse of time for the early Tertiary formations, equal to that assigned to the whole Lower Palæozoic.)

As a corollary to these general relative movements of continents

and ocean basins, the mechanics of mountain building are then discussed. It is plain that horizontal compressions are genetically connected with vertical movements: this is shown by space and time relations all over the world, since mountain building always occurs near the close of a revolution, after transgressional seas have largely disappeared. There are two sources of lateral pressures arising from changes in the physical state of the magma. Its liquefaction involves an increase of the earth's radius of about 6·5 miles, and therefore of the circumference by 41 miles. Most of this increase falls on the ocean floors. When solidification sets in the homogeneous continents are pressed upon by the descending ocean floors, giving rise to thrusts on the continents, and buckling the geosynclinal accumulations. More local and irregular changes of buoyancy must also occur, producing similar effects, probably on a smaller scale. The second great source of lateral compressional forces is that due to precessional and tidal effects; when the moon was nearer the last-named effect must have had a much greater braking power than now, as the horizontal tidal force varies inversely as the sixth power of the moon's distance. It is very important in this connexion to note that molten basalt is an extremely mobile liquid, as mobile as water and three times as heavy. Hence the tides in the molten isostatic magma ocean must have been very powerful. It is a fact of great significance that the greatest lava-floods of geological history have welled up on the western sides of continents or to the west of great mountain ranges, or have accompanied deep N—S rifts. It appears that volcanic activity must now be considered as in a state of decadence, as a surviving memorial of the last great revolution. Throughout the whole matter radioactivity is to be recognized as a dominant factor, being the greatest source of energy in the history of the globe, preparing the way for the mechanical effects of uplift, depression, tidal forces, and other lateral pressures, and under the conditions thus produced it is quite conceivable that there may have been continental drift, possibly as supposed by Wegener, possibly in other ways. Professor Joly does not discuss the details of this part of the subject.

The foregoing is believed to be a fair summary of this paper, which may probably be regarded as the most important contribution to its subject that has appeared in recent years. No summary can, however, do justice to the original, which is packed tightly with brilliant theory and corroborative evidence based on physical calculations. No general criticism of the conclusions will be here attempted: it must suffice to say that the argument for periodic world-revolutions, due primarily to the conversion of radioactive energy into heat, is extraordinarily convincing, and we do know as a fact that in past times world-wide periods of disturbance have alternated with ages of almost equally world-wide quiescence. We may, perhaps, venture to suggest that Professor Joly has not

taken into sufficient account some of the greater crust-disturbances that affected the southern hemisphere; the origin of the mountain chains of Cape Colony and the intrusion of the Karroo dolerites, probably the greatest of all effusions of basaltic magma, do not fit very well into his scheme, as they seem to have occurred just before the great late-Mesozoic transgression, between the Armorican and the Laramide revolutions. Professor Joly is careful to interpret geological contemporaneity in a very broad sense, but this must not be carried too far, or the conception of world-wide alternations of revolution and quiescence will lose much of its force.

R. H. R.

The Geology and Ore Deposits of the Tavoy District. By J. Coggin Brown and A. M. Heron. Mem. Geol. Survey, India, vol. xliv, pt. 2, pp. 167–354, with 8 plates. 1923. Price Rs. 6 As. 8.

OWING to the great demand for tungsten ores for special steel for munition purposes, the geology of Tavoy came into great prominence during the war. Unfortunately, several errors crept into published descriptions and gained wide currency. The present reviewer, among others, in all good faith and on the strength of categorical statements in the publications of the Geological Survey of India, helped to propagate one or two of these errors, especially with regard to the supposed presence of columbite in this area. In the present memoir we have a definitive description of the geology of the Tavoy district, with detailed accounts based on minute personal investigation of the ore deposits and the mineral character of the lodes. This subject is of particular interest, especially as regards the order of deposition of the different minerals, and has given rise to a good deal of controversy, as set forth in papers read and discussions at meetings of the Institution of Mining and Metallurgy and in articles in the *Mining Magazine*. The phenomena here to be seen have an important bearing on theories of ore-genesis, the most important point being as to whether tin or tungsten ores form at the higher temperature. Dr. W. R. Jones holds that cassiterite is the higher-temperature mineral and that there is, therefore, a probability of a tin zone below the tungsten zone of Tavoy: in the Malay States, on the other hand, owing to deeper denudation most of the tungsten zone has been removed, exposing the rich tin zone. Dr. Morrow Campbell controverts this idea, and maintains that wolfram is always deposited before cassiterite where the two come together. The subject is obviously of much practical importance, owing to the possibility of finding tin below known tungsten fields. The relations of the Cornish lodes, which have been carefully studied, do not on the whole lend much support to Dr. Morrow Campbell's view, but are more in favour of the theory of Dr. Jones, though not conclusive either way. A special point of some interest is that tourmaline does not appear in the ore-

association of Tavoy, though occurring in some later pegmatites, while fluorite is widely distributed: this suggests the absence of boron from the mineralizing portion of the magma.

The authors of this memoir give in their general conclusions an excellent summary of present-day views as to the mutual relations of magmatic differentiation, formation of pegmatitic segregations, and the phenomena summed up under the general heading of pneumatolysis. On the whole, they adhere to the view now gaining ground that this last term has been overworked, and that its application to the normal phenomena of granitic differentiation (e.g. formation of pegmatites) is quite unnecessary and an unwarranted extension of the original meaning. The greatest importance is attached to magmatic water as the agent of vein-formation.

The geology of Tavoy is simple in its general lines. The Mergui sedimentary series, probably Palæozoic, is invaded by great masses of granite, the visible outcrops probably forming domes and cupolas on a continuous bathylith lying along the axes of a fold-system. This fold-system is generally interpreted as forming part of the Burmese-Malayan arc of Suess. However, the age-relations of the folding and granite formation are somewhat obscure. The Malayan granites are generally believed to be Mesozoic: they may be Permo-Carboniferous, but on this point more information is needed, especially as to their relation to the Tertiary fold-systems of southern Asia. In nearly all writings on these mountain chains there is apparent a degree of vagueness as to relative ages, stress usually being laid on parallelism rather than on contemporaneity as the dominant condition. This has led to some confusion of thought on this matter. It seems probable that the study of the relative ages and types of the mineralization in different parts of these folded regions, in Burma, the Malay Peninsula, New Guinea, eastern Australia, and New Caledonia, may help to throw light on the general tectonics and structural history of this important element of the earth's crust.

R. H. R.

An Introduction to Stratigraphy. By L. D. Stamp. pp. xv + 368 with 84 figures. Thomas Murby & Co. 1923. Price 10*s*.

Dr. Stamp is to be congratulated on producing a textbook which shows that stratigraphy is the natural outcome of a series of continually changing conditions following one another in an orderly sequence. Geological facts of observation are definite, but often disconnected, and we frequently find that authors who may be willing in lectures to give voice to theoretical conceptions of how these facts came to exist, are chary of putting this conjectural matter on paper. We must therefore thank Dr. Stamp for taking the plunge with the enthusiasm and assurance which

are necessary to make the history of our Islands appear the outcome of a connected series of geological events.

With reference to detail, "some writers will find in this book some of their own pet theories almost, if not completely, ignored." This is particularly the case with regard to the Devonian and its lower limit, and it is a pity to find Dr. Stamp's "own pet theory" here to the entire exclusion of other views, while when we come to the vexed question of the division between the Permian and Trias (p. 180) or the Gault of Leighton Buzzard (p. 253), we find the various views of the subject clearly summarized.

We also note in the Preface that "an apology is tendered to very many authors who will find their work incorporated herein without its source being indicated"; this must presumably also refer to some of the diagrams which, although re-drawn, appear to be based on already published work. It must be on these points that "the writer craves especially the indulgence of older geologists".

The palæontology, especially in the Palæozoic, seems to be rather lax, and it is doubtful if the space given to the economic geology of each system is sufficient to justify its insertion at all. Nevertheless, this book will be of great use to the student of British Stratigraphy as it will enable him to picture the gradual development of our Isles, and see how the otherwise dry facts are the natural outcome of the evolution of this part of the globe.

W. B. R. K.

REPORTS AND PROCEEDINGS.

BRITISH ASSOCIATION, LIVERPOOL, 1923.

List of Papers read in Section C.—Geology.

1. Presidential Address by Miss G. L. Elles, D.Sc.: Evolutional Palæontology in Relation to the Lower Palæozoic Rocks.
2. Professor P. G. H. Boswell: Lecture on the Geology of the Liverpool District.
3. Discussion on the Geography of the Liverpool District from Pre-Glacial Times to the Present; opened by Sir A. Strahan, F.R.S.
4. Mr. C. B. Travis: Recent Geological Changes on the Northern Shore of the Mersey Estuary.
5. Mr. T. A. Jones: The Middle Bunter Sandstones of the Liverpool District and their Pebbles.
6. Professor P. F. Kendall: On Quaternary Isostatic Readjustments in North-West Europe.
7. Professor P. G. H. Boswell: The Structure and Succession of the Silurian Rocks in the Eastern Part of the Denbighshire Moors.
8. Professor P. F. Kendall: The Formation of Inter-Lake Deltas.
9. Dr. R. L. Sherlock: The British Rock-salt Deposits.

10. Miss M. Workman: The Permian Rocks of Skillaw Clough.
11. Professor G. Hickling: The Tectonics of the Lancashire Coalfield.
12. Mr. G. Slater: Observations on the Nordenskiöld and neighbouring Glaciers of Spitsbergen, 1921.
13. Mr. K. W. Earle: Preliminary Report on the Geology of the Windward and Leeward Islands.
14. Mr. C. P. Chatwin: A new Gastropod Fauna from the Chalk.
15. Discussion on Metamorphism; opened by Dr. J. S. Flett, F.R.S.

Papers on Cognate Subjects read in other Sections.

Section E.—Geography.

Mr. W. Hewitt: The Physiographical Features of the Region around the Mersey and Dee Estuaries.
Professor J. W. Gregory, F.R.S.: To the Alps of Chinese Tibet.
Mr. R. R. Walls: The High Plateau of Brazil.
Mr. J. A. Steers: Orfordness.

Section H.—Anthropology.

Professor W. J. Sollas, F.R.S.: Miocene Man.

Section B.—Chemistry.

Professor W. Vernadsky: Alumosilicates.

CORRESPONDENCE.

A CRITICISM OF MR. S. H. WARREN'S VIEWS ON SUBSOIL PRESSURE-FLAKING OF FLINTS.

Sir,—We have already had occasion to expose to the archæological world[1] the gross errors underlying the work of Mr. S. H. Warren in connexion with the subject of the fracture of flint. We have shown that he employed entirely wrong units in which to express many of his measurements; that he is guilty of grave errors in his use of elementary mathematics and mechanics; and that his experiments were conducted under conditions which rendered the results of no scientific value.

We regret to find that he is continuing to promulgate some of these errors and misstatements in a paper on "Subsoil Pressure Flaking", published recently as a Presidential Address to the Geologists' Association.[2] It becomes necessary, therefore, for us to direct the attention of geologists to some of the errors underlying the work of this author, and again to express our determination to expose such errors whenever they are brought to our notice.

[1] *Man*, vol. xxiii, April, 1923, No. 32; June, 1923, No. 51; August, 1923, No. 74.
[2] *Proc. Geol. Assoc.*, vol. xxxiv, 1923, pt. iii.

We will first examine the foundations upon which Mr. Warren bases his work.

On the first page of his Presidential Address, he states that his "first principles" are (1) the planes of least resistance and (2) chip and slide.

In dealing with the planes of least resistance, Mr. Warren claims that a piece of flint of plano-convex form, provided it be of reasonably good quality and not flawed, gives us four planes of progressive resistance to flaking, as illustrated in his diagram fig. 19 (p. 154 loc. cit.). We desire to point out that, for any given specimen, the number of planes revealing a progressive increase in resistance to fracture, so far from being restricted to four, is *infinite*. Further, Mr. Warren attempts, in a single diagram (fig. 19 loc. cit.), to specify the position of "four planes of progressive resistance to flaking", designated α, β, γ, and δ, in relation to a specimen of flint of plano-convex form. This, as anyone possessing an elementary knowledge of solid geometry knows, is a physical impossibility, and the directions of all the lines shown in Mr. Warren's diagram are indeterminate. In fact, an infinite number of planes may be drawn, each containing one of the lines shown in Mr. Warren's diagram, and it cannot be said that any one of the lines in question represents any one of these planes rather than another. The whole conception is chaotic, indeterminate, and scientifically valueless, but it is presented by Mr. Warren to the members of the Geologists' Association as one of his "first principles", of which he says "it is not going too far to say that no real understanding of mechanical flint flaking is possible until its bearing has been properly grasped".

Mr. Warren's second "principle" is "chip and slide".

This concept, the absurdity of which has been exposed by one of us in the *Proceedings of the Prehistoric Society of East Anglia* (vol. iii, pt. iii), relates, we are informed, "to the comparative degree of stability of contact between any two stones in different relative positions." We may point out, however, that this depends upon the nature and stability of the matrix surrounding the stones in question, a factor which Mr. Warren does not take into account.

It is not to be wondered at that the application of these so-called first principles leads to a number of errors, some of which are amusing in their singularity. For example, we may consider briefly the "coefficient of resistance to flaking" dealt with by Mr. Warren in all seriousness on pp. 157–8 (loc. cit.). He states that, as the results of his experiments, he feels assured "that the coefficient of resistance to flaking (dealing with α flaking only) is not less than the square of the increase of thickness of the flint". In physical science a "coefficient" expresses the relationship of one quantity to a like quantity, and is, therefore, a "pure number"; in mathematics it is also a "pure number". An increase in thickness is, of course, a length, and the square of this is, necessarily,